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The effects of muscular and psychological readiness on the reaction time, movement time and force of a whole body response movement.

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THE EFFECTS OF MUSCULAR AND PSYCHOLOGICAL READINESS ON THE REACTION TIME, MOVEMENT TIME, AND FORCE OF A WHOLE BODY RESPONSE MOVEMENT

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DEDICATION

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ABSTRACT

The purpose of the research was to study muscular and psychological readiness for a whole body response movement by determining the effects of set position time and temporal uncertainty on reaction time, movement time and movement impulse. The research task was a foreward charge out of a set of track starting blocks which contained a strain gauge transducer system. Five performance measures (hand reaction time, foot reaction time, yard movement time, complete movement time, impulse) were used as dependent variables and these were interpreted as being indicative of readiness in both the temporal uncertainty and set time conditions. Twenty-four male, physical education students from the University of Windsor were used as subjects. The results for each dependent variable in each condition were analyzed separately by a one way analysis of variance with repeated measures and the Newman-Keuls multiple comparison test.

The research revealed that temporal uncertainty underwent a general increase as the length of a variable foreperiod increased, but that two distinct readiness peaks existed. The first peak was at the two second mark and the second peak was at the six second mark. In the set time trials, performance decreased appreciably as set time aged even though there was a minimum and constant amount of temporal uncertainty. It was concluded that both muscular and combined psychological and muscular readiness are important in a whole body response movement, and that as time in a set position and temporal uncertainty are increased, these types of readiness are significantly decreased.

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INTRODUCTION

An abundance of research in the field of experimental psychology has dealt with the effects of preparation and readiness on simple reaction time. Little research, however, has been carried out to study the effects of preparation and readiness on the reaction time, movement time, and force of movement of a whole body type response task, despite the fact that efficient whole body response and movement are required in many performance situations.

Common to many tasks involving a desired response to an awaited stimulus is a preparation interval during which the performer remains relatively stationary in a set position. The duration of the preparation interval may be controlled and this raises the problem of determining the maximum length of time a subject can spend in a set position and still achieve optimum performance; and also the problem of determining the components of whole body preparatory set and how they interact to achieve a readiness peak.

Motor learning psychologists refer to preparation period as a foreperiod and have found interesting relationships between length of foreperiod and the reaction time of simple response movements. Karlin (34), for example, found that reaction time increased with a lengthening of the foreperiod; and Woodrow (72), hypothesized that optimum readiness occurs after a foreperiod of about two seconds. A review of several studies in the area of information theory indicates that in a laboratory setting, the critical factor in the foreperiod phenomenon is the method of foreperiod presentation and the resultant amount of temporal uncertainty. It was assumed therefore, following a review of the literature, that time uncertainty is an important factor in a subject's inability to build up psychological readiness:

> ...with low time uncertainty, preparation for one of the signals would always be achieved at the right time...; whereas with high time uncertainty, there would sometimes be no preparation at all... (4:448)

The research of particular value, with respect to the present study, would be simple reaction time studies which use the foreperiod to study the effects of temporal uncertainty on reaction time. If preparation is visualized as being a negative function of uncertainty, the relationship becomes clearer: the greater the temporal uncertainty, the poorer the preparation.

By definition, simple reaction time implies a reaction to a known stimulus using a known response. The mapping of stimulus to response is one to one and in this case there is no stimulus-response uncertainty present.

It is possible however, to induce uncertainty and decrease readiness to respond by altering the preparation interval. This is accomplished by varying the length of the foreperiod.

Several authors (5, 7, 16, 34, 36), have controlled temporal uncertainty by altering the foreperiod. In situations in which the length of foreperiod is constant over a block of trials but different between blocks of trials, it has generally been found that simple reaction time increases as a function of foreperiod length. This holds true for foreperiods from about .5 seconds (7) to at least three hundred seconds (5). The decrements between the mean reaction times of two blocks of trials can be attributed, in part, to subject ability to time a short foreperiod better than a long one, and therefore, better predict the stimulus occurrence. Thus ability to anticipate stimulus may be a major factor in the studies using blocks of constant foreperiod lengths.

In order to negate the effects of improper timekeeping and to study the effects of uncertainty on reaction time, several authors (16, 28, 33, 50), have used experimental designs which employ a variable foreperiod.

It is this variable foreperiod design which has produced varying results, and over which some controversy still remains. Although readiness to respond is optimum when temporal uncertainty is low (20,34, 35, 44, 74), there is some disagreement as to when uncertainty is lowest during a variable foreperiod. Some researchers, using performance in a reaction time task as an indicator of readiness, have reported increasing readiness as foreperiod ages (16, 28). Others however, have found that as a variable foreperiod ages, readiness deteriorates and performance is adversely affected (33, 50).

The tendency for readiness to decrease may be explained by the fact that longer time periods involve greater temporal uncertainty than shorter ones, and conversely, results showing increasing readiness are usually explained by the fact that as time passes during the foreperiod the probability of a stimulus occuring during the next second continually increases. For example, if randomized foreperiods of from one to ten seconds are used, the probability of a stimulus occuring at one second is .1. At six seconds, the probability becomes .5, and if after nine seconds there has been no stimulus, the probability of a stimulus at the ten second mark is 1.0. It was this apparent controversy over readiness peaks in a variable foreperiod which was one of the main concerns in the planning of the present research.

Despite the myriad of studies that have been done concerning response time and movement time, researchers have seldom dealt with whole body response movement. Extrapolation from 'finger lift' reaction time studies suggests that temporal uncertainty would be an important factor in whole body response time. However, a second factor might also be important in the whole body task.

> ...one's response speed has been shown to depend upon the time allowed to prepare and the length of time one must stay prepared (Woodworth and Schlosberg, 1955). This buildup and maintenance of 'set' is thought to be related to the buildup and maintenance of muscular tension. (32:417)

Although muscular tension has not been definitely established as the main component of muscular 'set', it is logical to assume that in a task where the whole body has to be moved quickly following a stimulus, some type of muscular preparation and readiness is required. This being the case, readiness, to a certain extent, would involve muscular as well as psychological factors. The present study, therefore, was an attempt to determine the primary components of whole body 'set' or readiness, by looking at the reaction, movement, and force characteristics of a whole body response task, and the effects of both foreperiod and set time on these characteristics. Since temporal uncertainty was minimized in the set time trials, it was reasoned that if a subject was unable to hold muscular readiness at a peak, his performance following longer periods in the set position should logically be poorer than his performance following set time periods of shorter duration.

THE PROBLEM

Statement of the Problem

The purpose of the research was to study the effects of temporal uncertainty and muscular readiness on reaction time, movement starting time, and force generated during a whole body response to a predetermined stimulus. More specifically, an attempt was made to determine (a) the singular effects of muscular readiness on reaction time, movement time, and movement impulse, and, (b) the combined effects of muscular readiness and psychological readiness on these selected response characteristics.

Hypotheses

Drawing from existing research and empirical evidence, the following set of research hypotheses were developed for use in this study.

(1) As the length of the foreperiod increases, the reaction time following a predetermined stimulus increases.

(2) As the length of the time in a set position increases, the reaction time following a predetermined stimulus increases.

(3) As the length of the foreperiod increases, the movement starting time of a desired response to a predetermined stimulus increases.

(4) As the length of the time in a set position increases, the movement starting time of a desired response to a predetermined stimulus increases.

(5) As the length of the foreperiod increases, the impulse generated during a desired response to a predetermined stimulus decreases.

(6) As the length of the time in a set position increases, the impulse generated during a desired response to a predetermined stimulus decreases.

Basic Assumptions

Prior to an investigation of the problem and hypotheses, the following basic assumptions were made.

(1) A certain degree of psychological readiness is a prerequisite for optimum performance in a whole body response task.

(2) Temporal uncertainty is an important factor in a person's inability to attain psychological readiness.

(3) The greater the psychological readiness, the better the performance will be.

(4) In a whole body type movement, muscular readiness is also an important factor affecting performance level.

(5) Performance will improve as muscular readiness increases.

(6) Psychological readiness is affected by temporal uncertainty during a variable foreperiod situation.

(7) Muscular readiness is affected by time spent in a stressful set position even when psychological uncertainty is removed.

(8) A pre-stimulus warning signal appreciably reduces the amount of temporal uncertainty during a foreperiod or set time.

Importance of the Problem

Knowledge of optimum readiness is important because if the foreperiod or set time is too short, the subject may not be ready to respond and if they are too long he may be past his readiness peak. Research of readiness for whole body reaction and movement could help to clarify the relationship between whole body movement and the 'finger lift' type movements of much of the related research. It could produce testable hypotheses concerning the ability of synergistic muscle groups to develop and maintain optimum readiness during a period of preparation, and finally, it could be used in a more practical sense by performers, human factors engineers, teachers and coaches in attempting to manipulate preparation periods in order to create either optimum or minimum reaction time, movement time, and force of the movement.

The research proposed is also important because it seeks to further explore the variable foreperiod as a method of inducing temporal uncertainty. The uncertainty versus warning signal situations should give some indication of a subject's ability to anticipate and predict stimulus occurrence under two conditions of uncertainty, and the use of the whole body response task should produce evidence concerning the different effects of psychological and muscular readiness on response movements.

Although research has indicated that length of foreperiod does have an effect on readiness (16, 33, 34, 35, 36, 50, 69, 72, 74), most studies deal solely with psychological preparation for simple finger and hand response movements in a laboratory setting. To this point in time, only a few researchers (19, 47, 63, 68, 69) have dealt with this problem in terms of whole body response and movement. Even fewer have attempted to link muscular preparation during a period in a set position to change in reaction time, movement time, and force of movement of a whole body reaction task.(14, 63).

Delimitations

Twenty-four males between the ages of nineteen and twenty-six volunteered to act as subjects, and each was tested under two different conditions; the one involved with studying the effects of psychological preparation on whole body response characteristics and the second, with studying the effects of muscular preparation on whole body response characteristics. The response task was a foreward charge out of a starting block apparatus which contained a strain gauge transducer system. Response times were measured to one one-thousandth of a second, and movement times to one one-hundredth of a second. The horizontal impulse of the left leg thrust was taken as a relative measure of the force of the response movement. The chronoscopes and strain gauges were checked for reliability of measurement, and prior to each testing session the balance, sensitivity, and calibration of the research equipment was checked for the purpose of maintaining consistency of measurement.

DEFINITION OF TERMS

For the purpose of enhancing the clarity of the study and avoiding semantic misunderstandings, the following operational definitions were used throughout the execution of the study.

Foreperiod. The foreperiod (FP) was that period during each trial which existed between the initial ready command and the stimulus light.

Time in a Set Position. Set position time (ST) was the time that each subject actually spent in a set position before each response during the trials which employed a pre-stimulus warning signal.

Hand Reaction Time. Hand reaction time (HRT) was that time which elapsed between the appearance of the final stimulus and the first overt movement by the support hand in an upward and foreward direction.

Foot Reaction Time. Foot reaction time (FRT) was the time taken, after the stimulus, for the left foot to begin exerting force on the starting block in a horizontal direction.

Starting Movement Time. Starting movement time was measured as the time between the subject's initial support hand movement and his completed movement across a one yard space (YMT).

Force of Movement. A relative measure of force generated during each trial was taken by recording the total horizontal impulse (IMP) (force x time) generated by the thrust of the left foot against the starting blocks transducer system.

Whole Body Response Time. Whole body response time was taken as a composite measure of the subject's response and movement times. It was intended as a measure of the time taken for a subject to begin movement and complete a movement across a one yar space (CMT).

ORGANIZATION OF THE REMAINDER OF THE THESIS

The remainder of the thesis is divided into five sections. Chapter II presents an analysis of the related literature. Chapter III describes the apparatus and experimental methodology. In chapter IV is found a report on the research results. Chapter V contains a discussion of the thesis findings. Finally chapter VI presents a final summary and conclusions.

CHAPTER II

REVIEW OF LITERATURE

The purpose of the research was to study preparation for a whole body response movement by looking at the effects of both a foreperiod and a set time period on the reaction time, movement starting time, complete movement time, and impulse of a whole body response task. An analysis of related literature revealed that much work has been done in the area of psychological readiness for fine motor movements in a laboratory setting, but that researchers have seldom dealt with whole body response movements or muscular preparation.

FOREPERIOD AND PSYCHOLOGICAL READINESS

The term 'preparation' as used by Bertelson and Barzeele (4) refers to a state of psychological readiness to react to an awaited stimulus. This phenomenon has alternately been termed readiness, preparatory set, attention, expectancy, and set, and a perusal of experimental psychology journals reveals an abundance of research concerning this topic.

The first research reported in the area of readiness was that of Woodrow in 1914. He found that of all foreperiods between one and twenty-four seconds, the two second foreperiod seemed to produce optimum reaction time (72). Some authors (see Teichner 64) attempted to either verify or disprove these findings, but it was not until after the linkage of reaction time studies to information theory by Hick (27) and Hyman (29), that the study of preparation and temporal uncertainty in reaction time began in earnest

Fine Motor Movement Studies

Although Teichner (64) in 1954 attempted to summarize what he called 'Recent Studies in Simple Reaction Time', the first new studies subsequent to Hick's work were done by Klemmer (35, 36) at the Air Force Cambridge Research Center.

In 1956, Klemmer (36) carried out a study designed to link reaction time to subject uncertainty due to imperfect timekeeping and presentation time variability. Using a visual stimulus, six subjects, and foreperiods from one to eight seconds, he designed an experiment in which the foreperiods were varied between blocks of trials in one condition, and within blocks of trials in a second condition. In the variable foreperiod trials, mean reaction times increased with mean foreperiod but the effect of foreperiod variability upon mean reaction time seemed to be greater for the trials with lower mean foreperiods.

Klemmer stated that varying the foreperiod in either of these two ways (constant or variable) would cause subject uncertainty and that within the limits of his study, uncertainty would cause a proportional increase in reaction times and therefore, a decrease in readiness to respond.

One qualification made was that the uncertainty effect in the variable foreperiod trials was of less consequence than was expected and it seems possible, in view of subsequent research, that by varying the foreperiod within blocks of trials, Klemmer was actually reducing uncertainty because of increasing presentation probability.

A subsequent study by Klemmer (35), was based on the findings of his earlier study but in this instance he hypothesized a combined effect of timekeeping and probability uncertainty on reaction time. By combining the results of a reaction time and time prediction test, he was able to arrive at a single measure of reaction time as a function of the uncertainty of the combination. The results of the study show that when reaction time is used as a measure of preparation, it is a linearly decreasing function of readiness.

Although Teichner's study (63), was primarily concerned with the effects of tension on reaction time, he also looked at effects of foreperiod, and his results revealed some interesting findings. Constant subject pressure on a calibrated spring, throughout the entire foreperiod, was used as a measure of tension. Using foreperiods of from one to eleven seconds, his analysis of variance of reaction times showed a significant optimum reaction time ($F = 3.37$) after a five second foreperiod for each tension level. This finding would seem to indicate that for the first five seconds of the foreperiod, the subject was able to increase his readiness because of his feeling that a stimulus was imminent. After approximately five seconds, the tension situation caused the subject to lose his concentration, thereby causing a loss of readiness and subsequently a poorer reaction time.

Since the studies of Klemmer (35, 36), Teichner (63) and others had not supported Woodrow's two second optimum, and had in fact produced disagreement among themselves, Karlin (34) in 1959, designed an experiment concerned with "a more detailed determination of the shape of the functional relationship between reaction time and foreperiod in the region of Woodrow's optimum." (34:185)

The task used by Karlin was the release of a spring loaded reaction key following an audio stimulus. The various foreperiod lengths were given in blocks of twenty and were of constant duration during each block. Foreperiod lengths were .5, 1, 2, and 3.5 seconds. The resulting data showed that when using foreperiods between .5 and 3.5 seconds, the mean reaction time, when plotted versus foreperiod, produced an increasing uninflected curve. This finding agrees with Klemmer's and disagrees with Woodrow's results, but because of the low range of foreperiods used, Teichner's five second optimum could not, at that time, be refuted. Also, these results introduce the first evidence that a subject can prepare for a stimulus in less than a second of time.

A study of inter-stimulus intervals by Kroll in 1961 (37), produced some interesting findings which can be related to uncertainty, preparedness to react, and the foreperiod phenomenon. With inter-stimulus intervals from 50 to 500 milli-seconds, there was a linear decrease in reaction time, but after the 500 msec. mark reaction times began to increase. Although Kroll drew no conclusions regarding foreperiod per se, it may be that at the .5 second interval the subject's attention and readiness were at a maximum and as time passed after .5 seconds, readiness waned as uncertainty began to increase. Another finding was that if catch trials employing much longer foreperiods were used, there was a marked increase in reaction time. This again supports the hypothesis that readiness decreases as a function of uncertainty. The results of Kroll's work indicate that a certain minimum time is needed for the development of maximum response readiness; and that if the stimulus does not arrive near the readiness peak, readiness undergoes a linear deterioration as a function of elapsed time.

Unsatisfied with the explanations of expectancy and readiness, Botwinick and Brinley (6), in 1962, hypothesized that "the various aspects of 'set' are distinguishable, different in meaning, and independent." (6:568) Using constant foreperiods of from one to fifteen seconds, and stimuli presentation in two sense modalities, they, like Klemmer (36), found that use of a variable foreperiod had an adverse effect on reaction time. When the foreperiods were presented in variable series, there were significantly higher reaction times ($F = 52.78$) after the smaller foreperiod durations than there were after the same foreperiods used in a regular series. The mean simple visual and auditory reaction times of sixty-four subjects after both random and constant foreperiods, show that the effect of timekeeping uncertainty does not seem to have as much effect in the variable foreperiod trials. It must be realized however, that the lack of a significant F-ratio (4.36 $P > .01$) in the random trials may be due to the increasing probability of stimulus occurrence as the foreperiod ages.

An attempt to discover the components of reaction time led Houle, in 1965 (28), to undertake a study of reaction times as functions of foreperiods. Although the main problem of Houle's study is extraneous to the present study, some mention of his results is pertinent because of the foreperiod factor. Each of four subjects gave reactions following four foreperiods. Two conditions existed: first, the foreperiods were kept constant over blocks of trials, and second, they were varied from trial to trial. The results indicated that in condition one (foreperiod constant), reaction time increased as a function of foreperiod. In condition two (foreperiod variable), the reaction times decreased as a function of foreperiod length. These results show that although more uncertainty existed in the variable series than in the constant series, the changing probability of stimulus occurrence during the variable blocks produced a decrease in RT as foreperiod aged.

Further studies of the same general area by Bertelson and Barzeele (4) in 1965, and Botwinick and Thompson (7) in 1966, reaffirmed earlier findings that during blocks of trials using constant foreperiods, reaction time increased as foreperiod increases and readiness decreases. Botwinick and Thompson's results, although showing one point of inflection, suggest that even in a situation where a stimuli series follows variable foreperiods, the reaction times increase as foreperiod length increases.

In an analysis of his results from a 1959 study (34) and the conclusions from a 1940 study by Mowrer (46), Karlin (33) observed that for some reason it was difficult for a person to maintain peak readiness after the expected time of stimulus occurrence even though the probability of termination is an increasing function of the elapsed time during a given foreperiod. To examine this problem more closely, a study was undertaken in 1966, which used an auditory stimulus and key release reaction after foreperiods of unimodal and bimodal distributions. Within each block the first thirty stimuli followed the modal foreperiod length. Thereafter, catch trials of longer or shorter duration were inserted into the sequence periodically to test the hypothesis that readiness was not maintained. The results showed that for all unimodal and bimodal distributions, there was a tendency for average reaction time, and therefore readiness, to reach an optimum at or near the modal foreperiod and then to increase appreciably within the next two hundred milli-seconds. The results were of greater magnitude than those of Mowrer, and Karlin suggested that because Mowrer's task required a slower build-up of readiness, there may have been an inherent ability to hold a readiness peak longer. One further finding concerning readiness was that, on the average, maximum readiness could be attained in 150 msec. This figure is lower than that found by other researchers (34, 36, 50) and may reflect the nature of the task. The subject knew that the modal foreperiod was brief, and therefore, his readiness set could have begun to peak before the warning signal was given. This would allow readiness to be reached earlier than normal within the foreperiod.

In the same vein as Karlin (33), Zahn and Rosenthal (74) carried out a study to determine the effects of foreperiod frequency on reaction time. The study supported the hypothesis of Drazin (16) that the average readiness potential peaks at about the mean foreperiod interval and decreases rapidly when the period of expectation is over. The results also introduced two possibilities for the peaking effect and these were: (a), errors in time estimation and (b), the degree of expectancy of each stimuli presentation.

Recent years have produced studies which are somewhat more sophisticated than were the earlier studies. One such study in 1969 by Nickerson and Burnham (50), looked at variable foreperiods in a new manner. Recognizing that the decreasing reaction time function, when plotted against variable foreperiods, was probably influenced by the changing probability of termination, Nickerson and Burnham designed an experiment in which they claimed readiness and preparation would not be affected by this change in stimulus probability. They devised a computer process which could divide the foreperiod into epochs and used a heads or tails type decision by the computer to decide whether or not a stimulus would occur during each epoch. Theoretically, this kept the presentation probability at fifty percent for each epoch of time. The results of fifty reactions at different foreperiods by four subjects, showed a direct relationship between reaction time and mean foreperiod. "Reaction time tends to increase linearly with the logarithm of mean foreperiod over the range of means used." (50:454) A second discovery was that for foreperiods of less than .25 seconds, reaction times seemed to vary inversely with the duration. This would indicate that the subjects were generally not able to prepare for a stimulus earlier than .25 seconds after the warning signal and would contradict the findings of Karlin (33) that a subject can reach maximum psychological readiness after only .15 seconds.

The discovery by Bertelson and Barzeele (4) that readiness set was selective and of short duration as is seen by shorter reaction times to more probable events and longer reaction times with longer foreperiods, led to a study by Moss in 1969 (44). The purpose of Moss' work was to study the dynamic changes in set by "assessing the changes in preparatory set over short spans of time." (44:151) Choice reactions were taken in two blocks of trials with equal stimuli probability. The only change was that in the fixed event, the foreperiod was constant over blocks of trials, and in the variable event the foreperiod was variable within blocks. Analysis of the results showed that the variable event had consistently longer mean reaction times ($F = 24.43$ $P < .001$) than did the constant event. Also, reaction time was found to be inversely related to the foreperiod of the variable event. These results are interesting for two reasons. First, there is indication that even though time uncertainty is evident in the constant foreperiod event, reaction times for foreperiods in the variable event are higher than those for the same foreperiod in a constant event. This result can be taken as evidence that greater uncertainty is inherent in presentation time uncertainty than in timekeeping uncertainty and this contradicts the earlier findings of Houle

(28). Second, the results support Drazin (16), Houle (28), and Karlin (33) and disagree with the findings of Nickerson and Burnham (50) concerning the relationship between reaction time and variable foreperiods.

Whole Body Response Movement Studies

There have been a few studies done by researchers in various athletic fields which have dealt with movement performance in a manner similar to the present study. Research on ideal set time for sprint starters has dealt with starting movement time and also some research concerning swimming starts has touched upon the area of psychological readiness.

Nakamura (47) investigated the optimum time for holding a sprinter in the set position between the command 'set' and the gun. He compared foreperiods of 1, 1.5, and 2 seconds. Defining starting time as the time taken to lift the hands following the gun shot, Nakamura found that a 1.5 second foreperiod consistently produced the best starting times.

Unsatisfied that Nakamura's evidence was convincing enough to support the claim of a 1.5 second optimum, Walker and Hayden (69), undertook research to determine the optimum time for holding a sprinter in the set position. They defined starting movement time as the time between the gun and the breaking of contact with the blocks by the rear foot. Their results showed fairly conclusively that the period between 1.4 and 1.6 seconds was the readiness peak, and therefore, the time interval that produced the fastest movement.

A special sound key circuit and take-off board allowed Tuttle and Morehouse (68) to study the relationship between foreperiod and starting speed in swimming. They used foreperiods of from 1 to 2.2 seconds in .2 second intervals. An analysis of their data showed significantly faster starting times after the longer foreperiods. The two second time was judged to be the best, but it was not significantly different than the 1.6, 1.8 or 2.2 second foreperiods. It appears from these results that readiness is beginning to peak after about 1.5 seconds and continues to do so until about two seconds. After two seconds, readiness begins to drop.

The nature of most psychological experimentation, in the field of information theory, which has dealt with preparation, has not necessitated the study of foreperiod as a factor affecting force of reaction. The author has found no research related to this problem, but can only make inferences concerning it. It would seem that if speed of reaction and speed of movement are both improved by heightened readiness, it could be assumed that optimum preparation would also produce the most forceful movements. This assumption is further reinforced by the fact that speed of movement in the form of acceleration is an important component of force.

SET TIME AND MUSCULAR READINESS

Although controversy exists over the exact nature of muscular readiness, reasoning would lead to the conclusion that the better prepared a subject was, the quicker he could initiate movement, the faster he could move, and, the more powerful his movement would be.

Tension and Relaxation

After an analysis of pertinent literature, Kagan (32) concluded that muscular preparation involved the build-up of muscular tension. On the other hand, Smith and Whitley (62), and Smith (59), reported that muscular response and movement was fastest when the muscle was relaxed prior to the reaction movement. In spite of this controversy, it would seem that muscular tension is important in the type of whole body reaction task used in this research because tension in the prime movers of the hip and knee joint and in the support arm was unavoidable in the set position.

Although Smith (60), found no significant differences between responses for relaxed and tensed musculature ($F = .218$), he did report that during a tensed state, subjects gave a seven percent faster reaction time than they did in a relaxed condition. (60:552)

Berger and Mathus (3), studied pre-tensed and pre-relaxed conditions using a bench press movement and varying resistance loads. In the one condition, the subjects relaxed prior to the stimulus; in the other, they exerted maximum isometric force against the bar without moving it. Difference of mean t ratios for each of five load proportion conditions showed the pre-relaxed condition to be significantly faster for movement time in each condition. The author, however, qualified this finding by stating that fatigue was likely a factor in the isometric tension condition. It was this same type of fatigue factor which was expected to be of consequence in the present study.

Clarke (12), asked subjects to respond to an auditory signal, with a maximum contraction of the hand gripping muscles. Pre-stimulus tension was induced by gripping the dynamometer to specified values between 10 and 30 kg. Analysis of variance produced a significant F of 12.6 ($P < .05$) which indicated that the higher tension levels produced significantly lower reaction times, and this led Clarke to conclude that, "increased preparatory set, in the form of preliminary muscular tension, is effective in increasing the speed of reaction." (12:63). These results must be qualified by a statement to the effect that this improvement in reaction time was only observed at levels of tension increase up to 15 kg. Above 15 kg. no significant differences were found.

A study of the effects of positional tensioning on reaction latency and contraction speed of muscle by Schmidt (56), employed a knee flexion movement as the reaction task. Various levels of pre-task isometric tension were used, and the results produced significant differences in favour of tensioning. Analysis of variance ($F = 4.11$) at the .05 level of confidence showed reaction times to be significantly faster as positional tensioning was increased. An F-ratio of .003 however, showed no significant differences for movement speed.

Teichner (63), employed an arm flexion task, in which the subject pulled against a spring loaded lever during the foreperiod, to study the effects of tension on simple reaction time. Although his results were confounded by changing foreperiods, analysis of variance resulted in significantly lower reaction times after higher degrees of pre-task tension. The results of this study allowed Teichner to conclude that, "R. T. varies inversely with magnitude of muscular tension except for combined foreperiod-tension irregularity of presentation of a high degree." (63:284).

Related closely to the concepts of this research, was a study by Davis (14). Interested in set and muscular tension, Davis found that the tension of the responding muscle gradually built up during the foreperiod and that the reaction time achieved was directly proportional to the level of tension that was reached.

Duration of Holding Time for Muscular Tension

It might be assumed from Davis' work that the longer the foreperiod, the more tension would increase, and therefore the faster the response movement would be. This same conclusion might be extracted from many of the studies mentioned here. However, a second consideration must be made which is also central to the main problem of the research, and that is the question of how long a subject in a tensed position can maintain maximum muscular readiness.

Although Davis (14), and Lansing, Schwartz, and Lindsley (38), reported that muscular readiness can peak in .3 or .4 seconds following a warning signal, the nature of the set position trials, in the present research, demanded that the subject be in a tensed position for between one and nine seconds prior to the warning signal. The possibility arises, therefore, that adequate preparatory tension in the muscles will be very difficult to achieve after longer durations of set position time.

As Lippold, Redfearn, and Vuco (39) state, "If contraction is made voluntarily at a certain tension, progressively greater voluntary effort is needed to maintain it, until an end point is reached when the tension begins to fall." (39:121). In this case, even if fatigue does not set in, it seems logical to expect that if more effort is needed to hold a constant tension, movement following longer foreperiods would be less efficient.

If it is assumed, as it was in the present research, that the subjects, in attempting to maintain a state of readiness, voluntarily underwent isometric tensioning in the muscles of the thigh and leg, it becomes interesting to note the holding time for an isometric contraction.

Tuttle (67), analyzed isometric tension of both the back and the legs, and found that maximum tension was held only momentarily. Almost immediately, the tension level declined as did the level of force which the musculature could exert. After an analysis of related literature, Hettinger (75), arrived at the conclusion that maximum force in the forearm flexors began to wane during the first ten seconds of a tension situation. Royce (55) however, found that when he attempted to investigate the fatigue curve for static contraction, no appreciable decline in tension was evident until the fifteen second mark.

Moudgil and Karpovich (45) used an electric dynamometer to measure the intensity and duration of muscular contraction of the forearm flexors. Their results revealed that the true mean holding time for a maximum isometric contraction was 2.6 seconds. The range was from .6 to 6.7 seconds, and after the peak was reached, the force of contraction began to decrease. In some cases a second upsurge in tension was noted but in no cases did this reach the level of the initial contraction. The figures obtained by Moudgil and Karpovich seem to compare favourably with those obtained by Cotten (13). Cotten studied the relationship between the duration of voluntary isometric contraction and strength changes. During his study, he found that the duration of sustained isometric contraction of the flexors of the forearm was between 3.0 and 9.8 seconds. The mean duration was 5.6 seconds.

Although there is no certainty that the present study involves maximum isometric contraction, it is apparent that the set position presented a stressful position in which the subject must continually exert isometric force both in anticipation of a stimulus, and to hold himself up in the set position. It would therefore seem possible that muscular tension would be much lower after eight and ten seconds than after two or four seconds.

A review of literature has uncovered no studies which approach the problem of muscular readiness in a manner similar to this study. All of the studies purporting to analyze muscular preparation have used a regular foreperiod situation which means that psychological uncertainty was present and could possibly confound the results. The present study attempts to reduce psychological uncertainty by giving a one second prestimulus warning light. This, in effect, allows an analysis of the effects of the actual time spent in a set position, on the ability of the musculature to remain in a state of readiness for a reaction task, and; also allows a comparison of the effects of muscular versus a combination of psychological and muscular readiness factors, on the characteristics of a whole body response movement.

CONCLUSIONS

The research concerning preparation and readiness was studied in an attempt to derive concrete evidence that psychological and muscular uncertainty affect the performance of a whole body response task. This evidence was found to be lacking in both depth and diversity. The method and apparatus used to study the problem of readiness and its effects on whole body response movements are described in the following chapter.

CHAPTER III

METHODOLOGY

This research was undertaken in an effort to study the effects of both a foreperiod situation (combined psychological and muscular preparation) and a set time situation (muscular preparation) on the reaction time, movement time and force of a desired whole body response movement.

APPARATUS

The equipment, which is shown in Figure 1, included a strain gauge transducer system mounted in a set of track starting blocks,[1] a Beckman RP type two channel dynograph, a model CVP 1700 Tape Switch signal mat, a Dekan automatic performance analyzer, one Standard one-thousandth second chronoscope and two Cramer ten second programmed timers. Also employed were two electrical relay boxes, a power supply, two signal lights (stimulus and pre-stimulus), and a K and E compensating polar planimeter.

GENERAL PROCEDURES OF THE TESTING

Selection of Subjects

Twenty-four male physical education students at the University of Windsor volunteered to be subjects. Their ages ranged from nineteen to twenty-six yearswith a mean age of approximately twenty-one and one half years.

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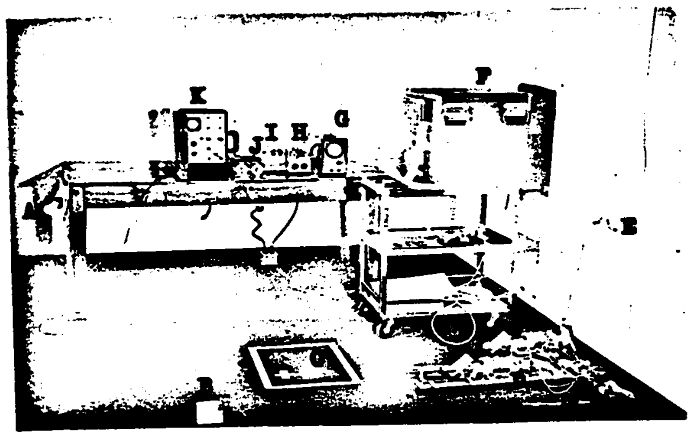
1 The strain gauge system was the same one as was used by P. J. Galasso. "The use of a Starting Blocks Transducer System in the Biomechanical Analysis of Sprint Starts", unpublished Ph. D. dissertation, University of Michigan at Ann Arbor, in 1968, (78).



Legend:

A. Pre-stimulus warning light.
B. Stimulus light.
C. Tape Switch signal mat.
D. Starting blocks transducer system
E. Stop on 'break contact' plug of the Dekan Automatic Performance Analyzer.
F. Beckman RP type dynograph.
G. Standard 1/1000 second chronoscope.
H. Two electrical relay boxes.
I. One power supply.
J. Two Cramer programmed timers.
K. Dekan Automatic Performance Analyzer.

Figure 1. Research Apparatus.

Determination of Individual Stances

Prior to testing, each subject was asked to assume a comfortable three point stance with his feet in the starting blocks. At this time, the Tape Switch signal mat placement was adjusted so that an X-mark would be directly under the support hand on each trial. Subjective appraisal of two subjects during pilot work indicated that if the support hand is placed on the same spot, the stance is relatively constant during each trial. The position of the starting blocks was kept the same for each subject so as to prevent foot spacing from confounding the results.

Preparation of the Subjects

Subsequent to the determination of individual stance preferences, each subject was allowed to take as many practice trials as he felt were necessary to familiarize himself with the task. It was observed that on the average, subjects took six or seven practice trials. When ready to begin, the subject was fitted with a special belt to which was attached a length of cord and the contact plug from the performance analyzer. This plug apparatus was designed so that its removal from the socket as the subject passed the one yard mark, would stop the chronoscope on the performance analyzer. Each subject was asked to cooperate in the testing by returning the plug to the contact socket after each trial.

A set of instructions (appendix C), was read before each set of trials and the apparatus was activated in order to familiarize the subject with the background noise and the appearance of the stimulus and pre-stimulus lights. The importance of a maximum effort on each trial was emphasized but the subject was also warned that he must perceive a stimulus before reacting; any false start (error trial), would invalidate the trial results and thus the trial would have to be repeated.

Following a brief pre-test interval during which the subject was instructed to sit and relax, the testing began.

Testing

Since the study involved two distinct problems and therefore different testing methodologies, each subject first completed the entire foreperiod trial test (FP), and then performed the set time trial test, (ST). The foreperiod trials involved a response following a variable foreperiod, and the set time trials employed a warning signal one second prior to each stimuli. During both series of trials, the equipment was activated manually by the researcher and was stopped automatically by performance of various elements of the task sequence (see Appendix A, Apparatus).

The two sets of trials were characterized by several common facets. In each case, the subject was asked to assume first a preparatory position and then, when he was ready, his particular set position. Both the foreperiod trials and the set time trials were presented in variable sequence. The time lengths chosen were two, four, six, eight and ten seconds, and their order of presentation (see TABLE I) was determined prior to testing, through the use of random selection with no replacement. Each subject was tested twice following each of the five time periods in each condition, and the order of presentation was the same for all subjects.

TABLE I
SEQUENCE OF FOREPERIOD AND SET TIME PRESENTATION

Trial Type	Time Duration (seconds)									
Foreperiod	8	4	2	10	4	6	10	2	8	6
Set Time	8	10	6	2	4	8	4	10	2	6

Although the above similarities did exist, several differences were also necessary in view of the fact that the foreperiod trials involved varying amounts of psychological uncertainty and the set time trials were designed to minimize the amount of uncertainty as to when the stimulus would occur.

During the foreperiod trials, the one Cramer programmed timer was deactivated and before each trial the other was set to the desired foreperiod duration. As the subject assumed his three point set position by placing his support hand on the X-mark of the Tape Switch signal mat, the experimenter called out the verbal command 'ready', and at the same time switched on both the electrical circuit and the Beckman dynograph. The closing of the switch and the subject's closing of the Tape Switch completed an electrical circuit and the Cramer timer began timing the pre-set foreperiod. As the timing device timed out, it closed the normally open switch in relay number one which simultaneously ignited the stimulus light. Concurrent with the onset of the stimulus, the Standard one-thousandth second chronoscope and the timer on the performance analyzer started. Also, the timer on the Beckman Dynograph marked the moving graph paper simultaneously with the onset of the stimulus. Thus, at the onset of the stimulus all of the equipment was made ready to take a reading.

As the subject began his response, the support hand was lifted from the Tape Switch signal mat, thus stopping the Standard one-thousandth second chronoscope. Continuing the movement, the subject crossed the horizontal distance of one yard and as he did, the 'stop on break contact' plug of the performance analyzer became disengaged from the socket and stopped the analyzer movement timer. As the subject completed the task, the dynograph and electrical circuit were shut off and preparation for the next trial began.

Since there was to be as little uncertainty as possible as to when the stimulus would occur, the set time trials were designed so that the subject would be presented with a warning signal one second prior to the stimulus. This necessitated the incorporation of a second programmed timer and a pre-stimulus warning light into the circuit. There was no ready signal when the subject assumed his set position, but the equipment was once again turned on and made ready to take a reading. The one Cramer timer was set for one second and the second one was set for one second less than the set time desired. For example, if an eight second set time was required, the first timer was set for seven seconds and the other for one second, giving a total of eight seconds in a set position. Once again the closing of the Tape Switch and the researcher's manual switch started the one timer timing. When the first timer timed out, it simultaneously activated the warning signal and the second timer. When the second timer, which was always set for one second, timed out, it performed the same function as the timer in the foreperiod trials. It ignited the stimulus, activated the chronoscopes, and marked the Beckman graph paper. Following the stimulus, the sequence of events was the same as that in the foreperiod trials.

Essentially, the equipment was designed with one purpose in mind, and that was to control the amount of temporal uncertainty before the response. The foreperiod trials involved varying amounts of uncertainty from two to ten seconds. In contrast to this, the set time trials involved only one second of uncertainty on each trial although in each case the subject had to spend similar amounts of time (two, four, six, eight, and ten seconds) in the set position.

Collection of Data

The collection of data involved the use of the equipment previously described. The nature of the equipment allowed measures of hand reaction time (HRT) and complete movement time (CMT) to be ascertained during the actual testing. Subsequent analysis was used to extract the foot reaction time (FRT), the yard movement time (YMT), and impulse (IMP) scores from the known time values and the Beckman Dynograph graph charts.

Hand Reaction Time. A direct measure of HRT during each trial was read off of the Standard chronoscope. During each trial, the measure was read, recorded, and the instrument reset, without the subject being able to see his score.

Foot Reaction Time. Foot reaction time (FRT), which was the time taken after the stimulus for the left foot to begin exerting force against the starting block, was determined by analyzing the Beckman graph paper. During each trial the onset of the stimulus sent an electrical impulse to the marker switch on the dynograph and a mark was placed on the paper. Since the paper speed of the chart paper was one hundred millimeters per second, FRT could be determined simply by measuring the distance between the stimulus and the point of initial rise of the force curve. This simple technique allowed direct measurement of reaction time to one one-hundredth of a second as a reading such as thirty-five millimeters would indicate a reaction time of .35 seconds.

Complete Movement Time. As was the case with HRT, CMT was taken directly off of a chronoscope during each trial. As the stimulus appeared, the remote start plug on the Dekan performance analyzer activated the chronoscope. As the subject passed a one yard mark, the 'stop on break contact' plug was pulled out of its socket and the chronoscope was stopped.

Although less accurate in terms of precision of measurement than the Standard chronoscope, the performance analyzer was checked against a one-thousanth second chronoscope for consistency. It was found that both the constant and variable error factors were fairly low (c = .004 sec., v = .0075 sec.), and therefore, it was determined that the equipment was suitable for use in the study.

Yard Movement Time. The actual time taken for the subject to move one yard during each trial was determined by subtracting the HRT from the CMT of the response. Since YMT was a measure of the time taken to move a one yard distance after the first hand movement, therefore:

$$YMT = CMT - HRT$$

Force x Time Integral (Impulse). A force curve for the horizontal drive of the left leg was recorded on the Beckman dynograph. Since the force of the leg thrust acting on the starting block was not constant, the integral of force x time of the thrust (impulse) actually consisted of the sum of FT's at every point along the baseline of the impulse curve. To measure this integral, a method similar to that used by Henry (22) was employed. A Paragon K + E compensating polar planimeter was used to measure the area under the FT curve. Since the desired measure of impulse was a relative rather than an absolute quantity, no conversion factor was used and the vernier units of the planimeter were simply used as units of impulse.

The relativity of the desired data also appreciably simplified the amount of calibration needed to extract the data through the use of a dynograph. To ensure accurate relative measures, the equipment was simply calibrated the same for each subject. Consistency was ensured by a recheck of the balance and sensitivity of the Beckman recorder prior to the testing of each subject.

DATA ANALYSIS

The following null hypothesis was formulated: As the length of foreperiod and the length of time in a set position increase, readiness to react quickly, move quickly, and generate force, during a whole body response movement is not affected.

Following the extraction of data from the chronoscope readings and the dynograph charts, several statistical procedures were carried out. The two scores (test and retest) of each dependent variable were added and the means found. This was done for the purpose of gaining more accurate estimates of the subject's true score. Following this, the means of the twenty-four subjects for each type of trial and each condition were added together and once again mean scores were found. Subsequent to this, representative graphs were constructed for each of the five dependent variables in each trial classification to see if obvious trends were apparent, and as a basis for comparison of the two treatment effects.

The data for each of the dependent variables in each treatment was analyzed by a one way analysis of variance with repeated measures (76: 105-132). The nature of the study and the subsequent desire not to commit a Type Beta error, dictated that the .05 level of confidence be used in analyzing the results. An F-ratio found to be significant at the .05

level of confidence was subjected to a further and more rigid test of significance, the Newman-Keuls multiple comparison method (76:80-82).

Additional statistical procedures were used in the hope that further information might help to clarify and explain some of the findings. With this purpose in mind, inter-correlation among all of the variables was carried out and a study of correlations between first and second trials was performed to determine the reliability of individual differences. Also, the true score variance (S^2_t) was calculated to determine whether any trends in subject similarity were evident in the actual test results as each subject performed the task after progressively longer durations of foreperiod or set time. Finally, correlated t tests were carried out to analyze the results of the foreperiod versus set time trials in order to determine whether significant differences existed between the combined effects of psychological and muscular readiness, and muscular readiness alone, on the reaction time, movement time and force of movement of a whole body response.

CHAPTER IV

RESULTS

The research employed both a foreperiod situation and a set time situation to study the effects of psychological and muscular preparation on the reaction time, movement time, and force of a whole body response task.

Data was collected for the five dependent variables in each treatment condition, and a computer program was used to perform ten one way analyses of variance with repeated measures (73:105-132). The .05 level of confidence was accepted as the significance threshold for both the analysis of variance and Newman-Keuls multiple comparison test results. By accepting significance at this level of confidence, it was assumed that a Type Beta error would be avoided.

COMBINED PSYCHOLOGICAL-MUSCULAR READINESS (FOREPERIOD TRIALS)

The foreperiod trials during the test and retest phases of the study involved varying amounts of temporal uncertainty which were expected to affect performance in the response task. Each of the scores listed in the following sections is a measure of the mean performance score of forty-eight trials following each time duration in both phases of the study.

Hand Reaction Time

The mean scores and standard deviations for HRT in the foreperiod trials are listed in Table 2. The data was accurate to .001 sec. and the mean scores ranged from .2656 seconds to .3018 seconds. Analysis of

TABLE II

MEAN HAND REACTION TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	2	4	6	8	10
Mean (sec.)	.2662	.2845	.2656	.2910	.3018
Standard Deviation	.0479	.0354	.0329	.0353	.0375

TABLE III

ANALYSIS OF VARIANCE FOR MEAN HAND REACTION TIME FOLLOWING FIVE FOREPERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	12,064,000.0	23	524,521.6	
Within Groups	7,081,728.0	96	73,768.0	
Treatments	2,398,464.0	4	599,616.0	11.78**
Residual	4,683,264.0	92	50,905.0	
Total	19,145,720.0	119		

** Significant at less than the .05 level.

variance (Table 3) produced an F-ratio of 11.78 (4, 92), which was found to be significant at less than the .05 level. Subsequent analysis using the Newman-Keuls multiple comparison method (Table 4) produced further measures of significance. Both the 2 and 6 second foreperiods resulted in significantly faster HRT than the other three foreperiods. Also, the 4 second foreperiod was superior to the 8 and 10 second trials, and the 8 second trials were significantly faster than the 10 second trials.

Foot Reaction Time

The results for FRT show that it took longer following the stimulus for the left foot to begin exerting force against the starting blocks than it did for the hand to be lifted from the signal mat. FRT however, does present an alternate, if relative, measure of reaction time to supplement the HRT results.

The mean scores (data accurate to .01 sec.) for FRT showed a range of from .2728 seconds to .3166 seconds (Table 5). Analysis of variance for FRT (Table 6) resulted in an F-ratio of 6.83 (4, 92), which was found to be significant at less than the .05 level of confidence. Newman-Keuls analysis (Table 7) revealed that the only significant difference was between scores for the 6 and 10 second foreperiods; however, inspection of the data showed that the 2 second scores were also very close to being significantly better than the later trial scores.

Yard Movement Time

The time taken for the first yard of actual horizontal movement was desired as a measure of how fast the subject could move after his response movement had been started. The mean scores for YMT (Table 8)

TABLE IV

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN HAND REACTION TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)		6	2	4	8	10
		.2656	.2661	.2845	.2910	.3018
6	.2656		5	189*	254*	362*
2	.2661			184*	249*	357*
4.	.2845				65*	173*
8	.2910					108*
10	.3018					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms. res.}}\ Q_{95}$ (r, 92)			30.91	37.07	40.81	43.34

** Significant at less than the .05 level.

TABLE V

MEAN FOOT REACTION TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	2	4	6	8	10
Mean	.2826	.3036	.2728	.3045	.3166
Standard Deviation	.0730	.0769	.0650	.0797	.0697

TABLE VI

ANALYSIS OF VARIANCE FOR MEAN FOOT REACTION TIME FOLLOWING FIVE FOREPERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	510,960.0	23	22,215.0	
Within Groups	133,098.0	96	1,386.4	
Treatments	30,502.0	4	7,625.5	6.837**
Residual	102,596.0	92	1,115.2	
Total	644,058.0	119		

** Significant at less than the .05 level.

TABLE VII

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN FOOT REACTION TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)		6	2	4	8	10
		.273	.283	.304	.305	.317
6	.273		10	31	32	44*
2	.283		-	21	22	34
4	.304				1	13
8	.305					12
10	.317					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N}$ Ms res. Q_{95} (r, 92)			28.74	34.47	37.95	40.30

* Significant at less than the .05 level.

ranged only from .4066 seconds to .4186 seconds. Although the 6 second mark was once again the optimum foreperiod, the 2 second time produced the slowest YMT. The scores were so close however, that no trends were apparent and analysis of variance (Table 9) produced an F-ratio of only 1.92 (4, 92) which did not meet the requirements for statistical significance at the .05 level.

Complete Movement Time

The range of CMT scores following the five variable foreperiods was from .6765 seconds to .7016 seconds (Table 10). An F-ratio of 2.98 (4, 92) (Table 11), was found to be significant at the desired level of confidence. The Newman-Keuls analysis (Table 12) produced evidence that once again the 6 second foreperiod was significantly better than the 8 and 10 second foreperiods; also, the 2 second foreperiod was significantly better than the 10 second foreperiod.

Force x Time Integral

The mean IMP scores (Table 13) ranged downward from 102.7 units to 90.9 units, and a significant F-ratio of 4.64 (4, 92) was found through analysis of variance (Table 14). A subsequent analysis by the Newman-Keuls method (Table 15) showed the 10 second, 8 second, and 4 second foreperiod scores to be significantly lower than the scores following variable foreperiods of 2 and 6 seconds.

MUSCULAR READINESS (SET TIME TRIALS)

To alleviate the effects of temporal uncertainty during the set time trials, a one second warning light was given prior to each stimuli. Although this warning light allowed adequate time for psychological

TABLE VIII

MEAN YARD MOVEMENT TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	2	4	6	8	10
Mean	.4186	.4071	.4066	.4086	.4165
Standard Deviation	.0653	.0728	.0639	.0633	.0668

TABLE IX

ANALYSIS OF VARIANCE FOR MEAN YARD MOVEMENT TIME FOLLOWING FIVE FOREPERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	47,225,340.0	23	2,053,275.0	
Within Groups	3,957,504.0	96	41,224.0	
Treatments	305,408.0	4	76,452.0	1.923 **
Residual	3,652,096.0	92	39,696.0	
Total	51,182,840.0	119		

** No significant differences at less than the .05 level.

TABLE X

MEAN COMPLETE MOVEMENT TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	2	4	6	8	10
Mean (sec.)	.6828	.6868	.6765	.6967	.7016
Standard Deviation	.0712	.0719	.0525	.0643	.0645

TABLE XI

ANALYSIS OF VARIANCE FOR MEAN COMPLETE MOVEMENT TIME FOLLOWING FIVE FOREPERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	411,792.0	23	17,904.0	
Within Groups	87,248.0	96	908.0	
Treatments	10.000.0	4	2,500.0	2.977**
Residual	77,248.0	92	839.6	
Total	449,040.0	119		

** Significant at less than the .05 level.

TABLE XII

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN COMPLETE MOVEMENT TIME FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)		6 .677	2 .683	4 .687	8 .697	10 .702
6	.677		6	10	20*	25*
2	.683			4	14	19*
4	.687				15	15
8	.697					5
10	.702					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res.}}\ Q_{95}$ (r, 92)			12.58	15.09	16.62	17.65

* Significant at less than the .05 level.

TABLE XIII

MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	2	4	6	8	10
Mean	100.5	93.9	102.7	92.4	90.9
Standard Deviation	29.1	26.4	25.2	29.6	27.9

TABLE IXV

ANALYSIS OF VARIANCE FOR MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE FOREPERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	75,383.0	23	3,277.0	
Within Groups	15,576.0	96	162.0	
Treatments	2,615.0	4	653.0	4.640**
Residual	12,961.0	92	140.0	
Total	90,959.0	119		

** Significant at less than the .05 level.

TABLE XV

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE FOREPERIODS

Foreperiod (sec.)	10	8	4	2	6
	91	92	94	101	103
10 91		1	3	10*	12*
8 92			2	9*	11*
4 94				7*	9*
2 101					2
6 103					
Q_{95} (r, 92)		2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res. } Q_{95} (r, 92)}$		5.14	6.16	6.79	7.21

* Significant at less than the .05 level.

preparation (35, 51), the subject was instructed not to move until the actual stimulus arrived. Since the effects of temporal uncertainty were reduced to a minimum, it was reasoned that any changes in performance could be attributed to a muscular readiness factor—a muscular ability to move.

The same statistical procedures were followed with the set time trials as were used for the foreperiod trials, and here again, some statistically significant findings resulted.

Hand Reaction Time

The mean scores for set time trials HRT (Table 16) had a range of from .2371 seconds to .2657 seconds (data accurate to .001). Analysis of variance (Table 17) indicated a significant F-ratio of 13.5 (4, 92) at less than the .05 level. Newman-Keuls analysis was again used to determine the location of the differences (Table 18). The 2 and 4 second set times rendered scores significantly better than the 6, 8, and 10 second trials; 6 seconds was significantly better than 8 and 10 seconds; and, 8 seconds was significantly better than 10 seconds.

Foot Reaction Time

The times taken for the first horizontal force exertion by the left foot (FRT), ranged from .2271 seconds to .2545 seconds (Table 19). A significant F-ratio of 6.90 (4, 92) was found through the analysis of variance (Table 20), and the readiness trend appeared to be very similar to that of the HRT scores. Newman-Keuls analysis (Table 21) indicated that the 2 and 4 second set time trials produced scores significantly better than the 6, 8, and 10 second trials, and, the 6 second trials were significantly better than the 8 and 10 second trials.

TABLE XVI

MEAN HAND REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Set time (sec.)	2	4	6	8	10
Mean	.2374	.2371	.2452	.2545	.2657
Standard Deviation	.0279	.0259	.0249	.0265	.0367

TABLE XVII

ANALYSIS OF VARIANCE FOR MEAN HAND REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	7,024,128.0	23	305,396.0	
Within Groups	3,855,104.0	96	40,157.0	
Treatments	1,424,896.0	4	356,224.0	13.485**
Residual	2,430,208.0	92	26,415.0	
Total	10,879,230.0	119		

** Significant at less than the .05 level.

TABLE XVIII

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN HAND REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Set Time Period (Sec.)		4	2	6	8	10
		.2371	.2374	.2452	.2544	.2657
4	.2371		3	81*	173*	286*
2	.2374			78*	170*	283*
6	.2452				92*	205*
8	.2544					113*
10	.2657					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res.}}\ Q_{95}$ (r, 92)			22.33	26.79	29.49	31.32

* Significant at less than the .05 level.

TABLE XIX

MEAN FOOT REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Set Time Period (Sec.)	2	4	6	8	10
Mean	.2342	.2271	.2423	.2536	.2545
Standard Deviation	.0540	.0453	.0506	.0531	.0676

TABLE XX

ANALYSIS OF VARIANCE FOR MEAN FOOT REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	297,162.0	23	12,920.0	
Within Groups	59,622.0	96	621.0	
Treatments	13,766.0	4	3,441.0	6.904**
Residual	45,856.0	92	498.0	
Total	356,784.0	119		

** Significant at less than the .05 level.

TABLE XXI

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN FOOT REACTION TIME FOLLOWING FIVE SET TIME PERIODS

Set time period (sec.)		4	2	6	8	10
		.227	.234	.242	.254	.255
4	.227		7	15*	27*	28*
2	.234			8	20*	21*
6	.242				12*	13*
8	.254					1
10	.255					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N\ Ms\ res.}\ Q_{95}$ (r, 92)			9.72	11.66	12.83	13.63

* Significant at less than the .05 level.

Yard Movement Time

Unlike the results of the foreperiod trials, YMT in the set time trials did result in some statistically significant differences. The mean scores (Table 22) ranged from .3889 seconds to .4031 seconds. These are only slightly lower than the same set of figures for the foreperiod trials. Analysis of variance of YMT scores (Table 23) resulted in a significant F-ratio of 2.79 (4, 92). To find the location of the differences, Newman-Keuls analysis was again used. The results indicated that the 2 and 6 second set time periods resulted in significantly faster movement times than the 4, 8, and 10 second periods. Also, the 4 second trials were significantly better than the 8 and 10 second trials, and the 10 second trials were significantly better than the 8 second trials.

Complete Movement Time

Mean CMT scores for the five set time periods ranged from .6259 seconds to .6715 seconds (Table 25), and a high F-ratio of 17.9 (4, 92) was found to be significant at less than the .05 level (Table 26). Newman-Keuls analysis (Table 27) revealed that many areas of statistical significance existed. The CMT scores following 2,4, and 6 second set time periods were significantly better than the 8 and 10 second trial scores, and the 8 second scores were significantly better than the 10 second scores.

Force x Time Integral

The set time trials produced much higher IMP scores than the foreperiod trials. A range of IMP scores from 114.7 units to 99.3 units (Table 28) resulted in a significant F-ratio of 9.51 (4, 92) when sub-

TABLE XXII

MEAN YARD MOVEMENT TIME FOLLOWING
FIVE SET TIME PERIODS

Set time period (sec.)	2	4	6	8	10
Mean	.3889	.3944	.3901	.4031	.4001
Standard Deviation	.0603	.0633	.0668	.0596	.0689

TABLE XXIII

ANALYSIS OF VARIANCE FOR MEAN YARD MOVEMENT TIME
FOLLOWING FIVE SET TIME PERIODS

Source	Sum of Squares	DF	Mean Square	F-ratio
Between Groups	42,414,080.0	23	1,844,090.0	
Within Groups	3,378,944.0	96	35,197.3	
Treatments	365,824.0	4	91,456.0	2.792**
Residual	3,013,200.0	92	32,751.0	
Total	45,793,020.0	119		

** Significant at less than the .05 level.

TABLE XXIV

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR
MEAN YARD MOVEMENT TIME FOLLOWING
FIVE SET TIME PERIODS

Set time period (sec.)		2	6	4	10	8
		.3889	.3900	.3944	.4001	.4030
2	.3889		11	55*	112*	141*
6	.3900			44*	101*	130*
4	.3944				57*	86*
10	.4001					29*
8	.4030					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res. } Q_{95} (r, 92)}$			24.92	29.89	32.90	34.95

* Significant at less than the .05 level.

TABLE XXV

MEAN COMPLETE MOVEMENT TIME FOLLOWING
FIVE SET TIME PERIODS

Set time period (sec.)	2	4	6	8	10
Mean	.6259	.6308	.6353	.6584	.6715
Standard Deviation	.0668	.0677	.0603	.0663	.0715

TABLE XXVI

ANALYSIS OF VARIANCE FOR MEAN COMPLETE MOVEMENT TIME FOLLOWING FIVE SET TIME PERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	463,392.0	23	20,147.0	
Within Groups	84,224.0	96	887.0	
Treatments	36,960.0	4	9,240.0	17.985**
Residual	47,264.0	92	513.0	
Total	547,616.0	119		

** Significant at less than the .05 level.

TABLE XXVII

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR MEAN COMPLETE MOVEMENT TIME FOLLOWING FIVE SET TIME PERIODS

Set time period (sec.)		2 .626	4 .631	6 .635	8 .658	10 .672
2	.626		5	9	32*	46*
4	.631			4	27*	41*
6	.635				23*	37*
8	.658					14*
10	.672					
Q_{95} (r, 92)			2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res.}}\, Q_{95}$ (r, 92)			9.83	11.79	12.98	13.79

* Significant at less than the .05 level.

TABLE XXVIII

MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE SET TIME PERIODS

Set time period (sec.)	2	4	6	8	10
Mean	114.7	108.3	107.7	99.30	103.0
Standard Deviation	27.92	27.79	29.68	26.47	31.34

TABLE XXIX

ANALYSIS OF VARIANCE FOR MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE SET TIME PERIODS

Source	Sum of Squares	DF	Mean Square	F-Ratio
Between Groups	89,417.0	23	3,887.0	
Within Groups	11,192.0	96	116.0	
Treatments	3,276.0	4	819.0	9.518**
Residual	7,916.0	93	86.0	
Total	100,609.0	119		

** Significant at less than the .05 level.

TABLE XXX

NEWMAN-KEULS MULTIPLE COMPARISON TEST FOR
MEAN FORCE X TIME INTEGRAL FOLLOWING
FIVE SET TIME PERIODS

Set time period (sec.)	8 99	10 103	6 108	4 108	2 115
8 99		4	9*	9*	15*
10 103			5*	5*	12*
6 108				0	7*
4 108					7*
2 115					
Q_{95} (r, 92)		2.81	3.37	3.71	3.94
$\sqrt{N \text{ Ms res.}}\ Q_{95}$ (r, 92)		4.04	4.85	5.34	5.67

* Significant at less than the .05 level.

jected to one way analysis of variance (Table 29). Newman-Keuls multiple comparison test (Table 30) revealed that the 2 second trial scores were significantly better than the scores of all of the other time periods. Also, the 4 and 6 second trial scores were significantly better than the scores of the 8 and 10 second trials.

In all cases except the foreperiod YMT trials, significant F-ratios were found. Therefore, with that one exception, the null hypothesis that longer foreperios and set time periods do not affect reaction time, movement time, and force of movement, was rejected. It would appear therefore, that both psychological and muscular readiness factors are important considerations in increasing the performance level of a whole body response movement.

PSYCHOLOGICAL VERSUS MUSCULAR READINESS

Inspection of the graphed data for both types of readiness, and correlated t tests were used to analyze the differences between the effects of muscular and combined psychological and muscular readiness on performance. It is evident from an empirical analysis of the graphed data (Figures 2-6), that a combination of psychological and muscular readiness is a greater factor in performance than muscular readiness alone. This is suggested by the fact that the scores for the dependent variables were better in the set time trials than in the foreperiod trials. The high temporal uncertainty situation along with the muscular requirements of the set position decreased the effectiveness of subject performance.

The t ratios for the differences of means (Table 31) indicate that in all but three instances the mean score of the set time trial was

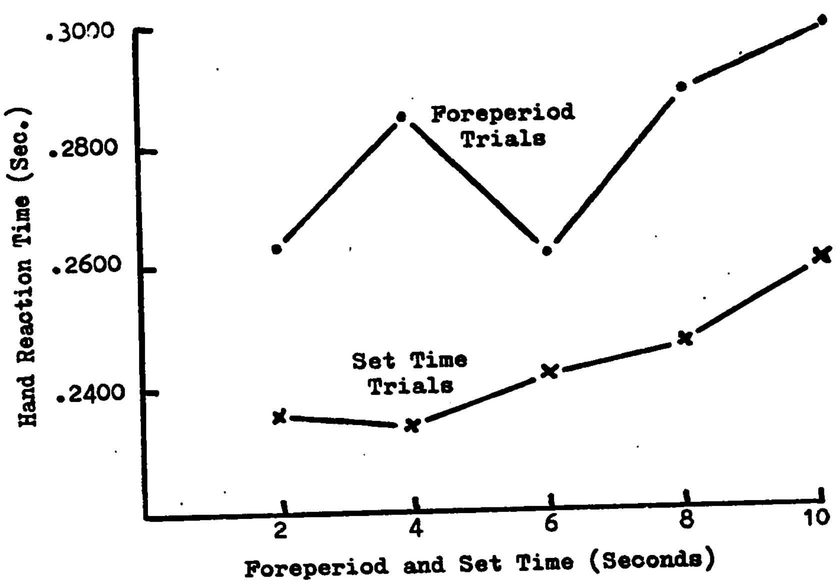


Figure 2: Hand Reaction Time for both Foreperiod and Set Time Trials.

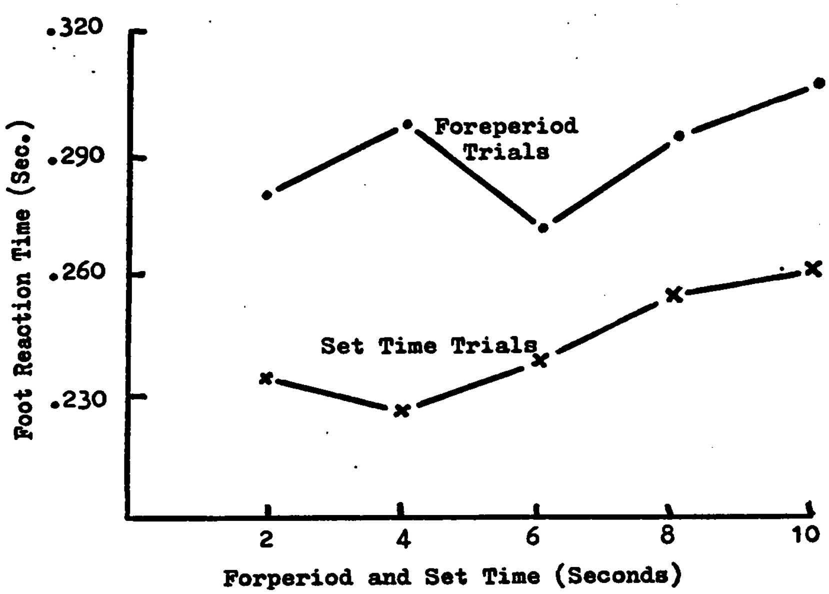


Figure 3: Foot Reaction Time for both Foreperiod and Set Time Trials.

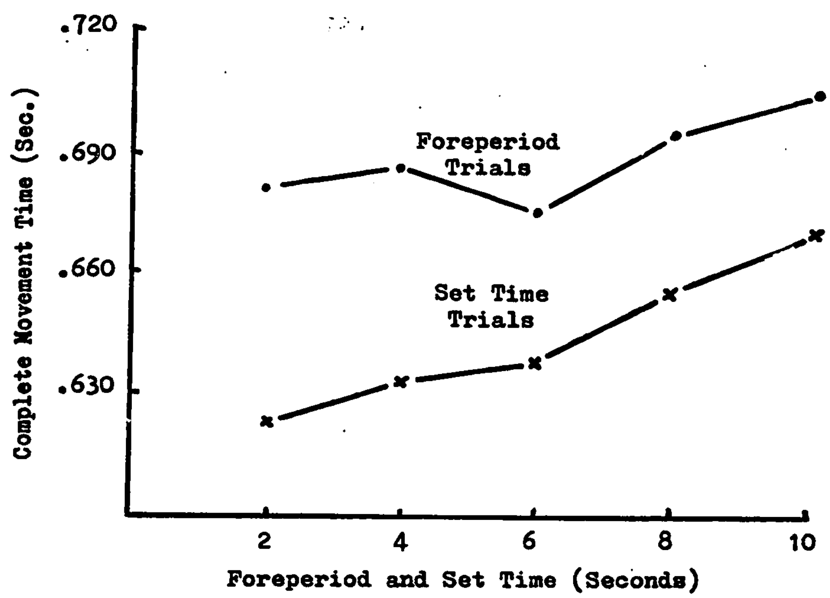


Figure 4: Complete Movement Time for both Foreperiod and Set Time Trials.

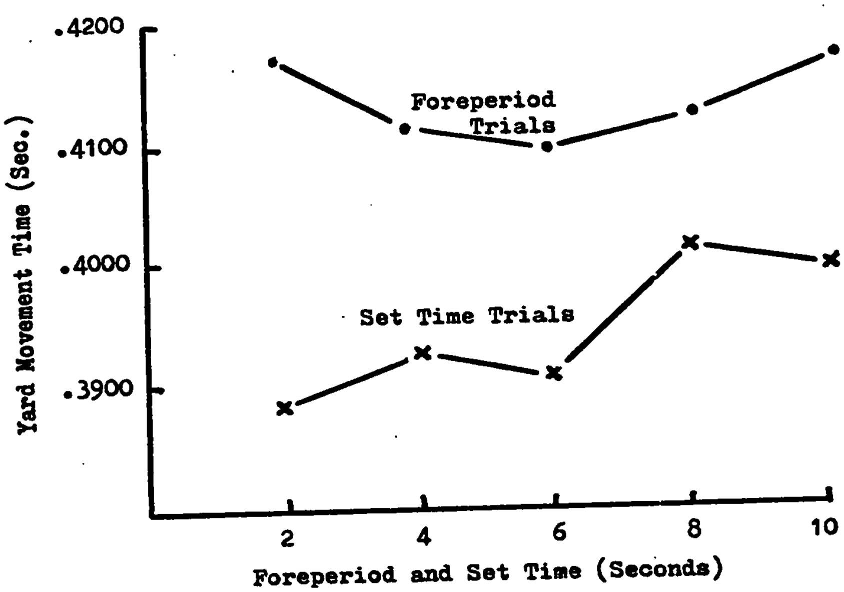


Figure 5: Yard Movement Time for both Foreperiod and Set Time Trials.

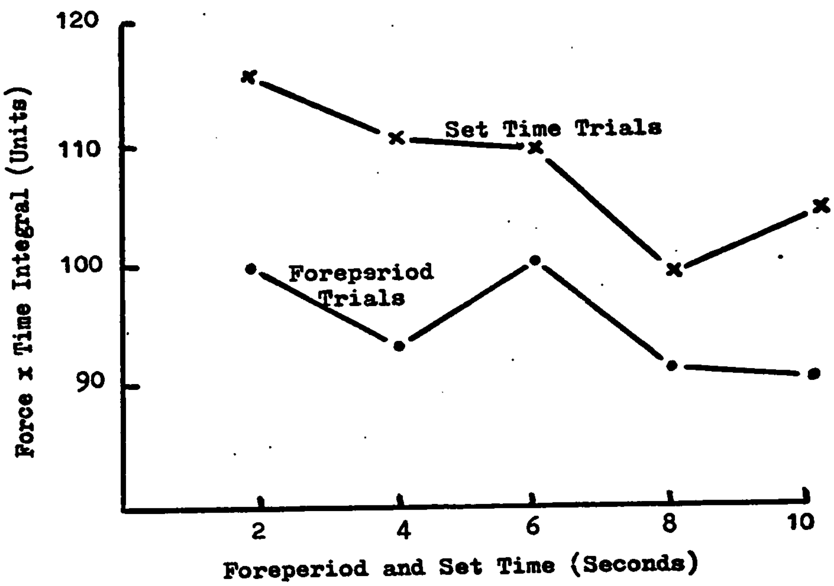


Figure 6: Force x Time Integral for both Foreperiod and Set Time Trials.

TABLE XXXI

CORRELATED SAMPLES t TEST FOR DIFFERENCE OF MEANS OF FOREPERIOD TRIALS AND CORRESPONDING SET TIME TRIALS

Foreperiod vs Set Time	2 vs. 2	4 vs. 4	6 vs. 6	8 vs. 8	10 vs. 10
HRT	2.87*	6.15*	3.70*	5.44*	3.65*
FRT	8.31*	7.65*	5.66*	16.6*	9.85*
YMT	5.12*	2.08*	2.96*	1.01	2.70*
CMT	10.6*	8.88*	7.88*	6.60*	3.24*
IMP	3.39*	2.92*	1.38	1.22	3.33*

* Significant at less than the .05 level.

significantly better than the corresponding foreperiod trial score.

Also of interest, is the fact that the reaction and movement times for the FP trials were in most cases three to six percent poorer than the ST scores, whereas the impulse scores for the FP versus the ST scores were up to almost fifteen percent poorer in some cases.

It was evident from the graphs and statistical analysis that the warning signal during the ST trials allowed psychological preparation prior to the stimulus. It was also apparent however, that even when a warning signal was given, muscular readiness could not be maintained during the longer set time periods.

CORRELATION

A computer program was also employed to derive a fifty x fifty correlation matrix involving the scores of the five dependent variables for each of the ten time periods (five foreperiods, five set time periods). The figures of most interest were the correlation coefficients for the reaction times versus the movement times, because a majority of the evidence in the simple reaction time studies indicates very low or no correlation between reaction time and movement time.

The results in this study also show low correlation between reaction time and movement time. For the five foreperiods, HRT versus CMT correlations ranged from r = .0016 to r = .4666. The range for HRT versus YMT was r =.2149 to r = .4307. For FRT versus CMT the range was r = .5454 to r = .6357, and FRT versus YMT the range was r = .2895 to r = .4392. For the set time trials the results were similar. The HRT versus CMT range was r = .1426 to r = .4434. The range for HRT versus YMT was r = .0156 to r = .2626. For FRT versus CMT the range was r = .5180 to

$r = .6565$, and for FRT versus YMT, $r = .5048$ to $r = .5963$ was the range.

Although some of the figures approached or met the requirements for statistical significance ($r = .40$, $P < .05$), it seems that in nearly all cases, the coefficients were too low to be very meaningful, and in view of the general findings concerning the reaction time versus movement time question, no unusually different results were found.

RELIABILITY OF IN DIVIDUAL DIFFERENCES

Since the actual testing involved two trials per time duration, a study of the correlation coefficients between the first and second trial scores of each dependent variable for each trial type was carried out. This type of information is important because it gives a measure of reliability of individual differences among the subjects.[1] Table 32 shows the reliability correlations for all trials, and generally the correlations were found to be in a medium range. The range was from $r = .4347$ for set time HRT (4 sec. vs 4 sec.), to $r = .9483$ for foreperiod YMT (6 sec. vs 6 sec.). Of the fifty correlation coefficients obtained, all were above $r = .4300$, forty-five were above $r = .5000$, forty-one above $r = .6000$, thirty-five above $r = .7000$, twenty-three above $r = .8000$, and, six above $r = .9000$. In general, it is apparent that the results of this study show moderately high reliability of individual differences although it must be recognized that in some cases a good deal of the variance might possibly have been due to intravariability (S^2_i), or experimental error (S^2_e).

1 If a coefficient of .80 were found for the first versus the second trial of any condition, it would serve to indicate that eighty percent of the variance could be explained by individual differences, but that twenty percent of the variance was due to intravariability and experimental error.

TABLE XXXII

RELIABILITY CORRELATIONS FOR
TEST-RETEST SCORES

Trial vs. Trial	2 sec. vs. 2 sec.	4 sec. vs. 4 sec.	6 sec. vs. 6 sec.	8 sec. vs. 8 sec.	10 sec. vs. 10 sec.	Mean
FP HRT	.7767	.5866	.7215	.4423	.6249	.6304
FP FRT	.8285	.7016	.6913	.6238	.7171	.7124
FP YMT	.8882	.9084	.9483	.8199	.9348	.8999
FP CMT	.8816	.7780	.8949	.6735	.8188	.8093
FP IMP	.7515	.6860	.4416	.7623	.6946	.6672
ST HRT	.5257	.4347	.7369	.4473	.5773	.5444
ST FRT	.5646	.7144	.8837	.4670	.7196	.6698
ST YMT	.8058	.9305	.9342	.8508	.8662	.8775
ST CMT	.8591	.8291	.9246	.8588	.8193	.8582
ST IMP	.7799	.8351	.8008	.8242	.7891	.8057

TRUE SCORE VARIANCE

In an effort to determine whether aging foreperiods or set time periods caused individuals to become more or less alike in performance, the true score variance (S^2_t) for each performance was extracted from the data. The results of this analysis, shown in Figure 7, revealed several areas of appreciable inflection in the variance curves, but, no general trends were apparent for the true score variance of all of the scores. It appears therefore, that changes in neither combined psychological and muscular readiness nor muscular readiness affected the magnitude of the individual differences in any consistent manner. This conclusion was supported by the fact that there were no consistent trends between the (S^2_t) scores for long versus short foreperiods or for long versus short set time periods.

As has been indicated, several statistically significant results were obtained. These results contain information concerning both psychological and muscular readiness for a whole body response movement. Chapter five presents a discussion of readiness in light of the present research and related literature, and also a general discussion of the study and its implications for further research direction and practical application.

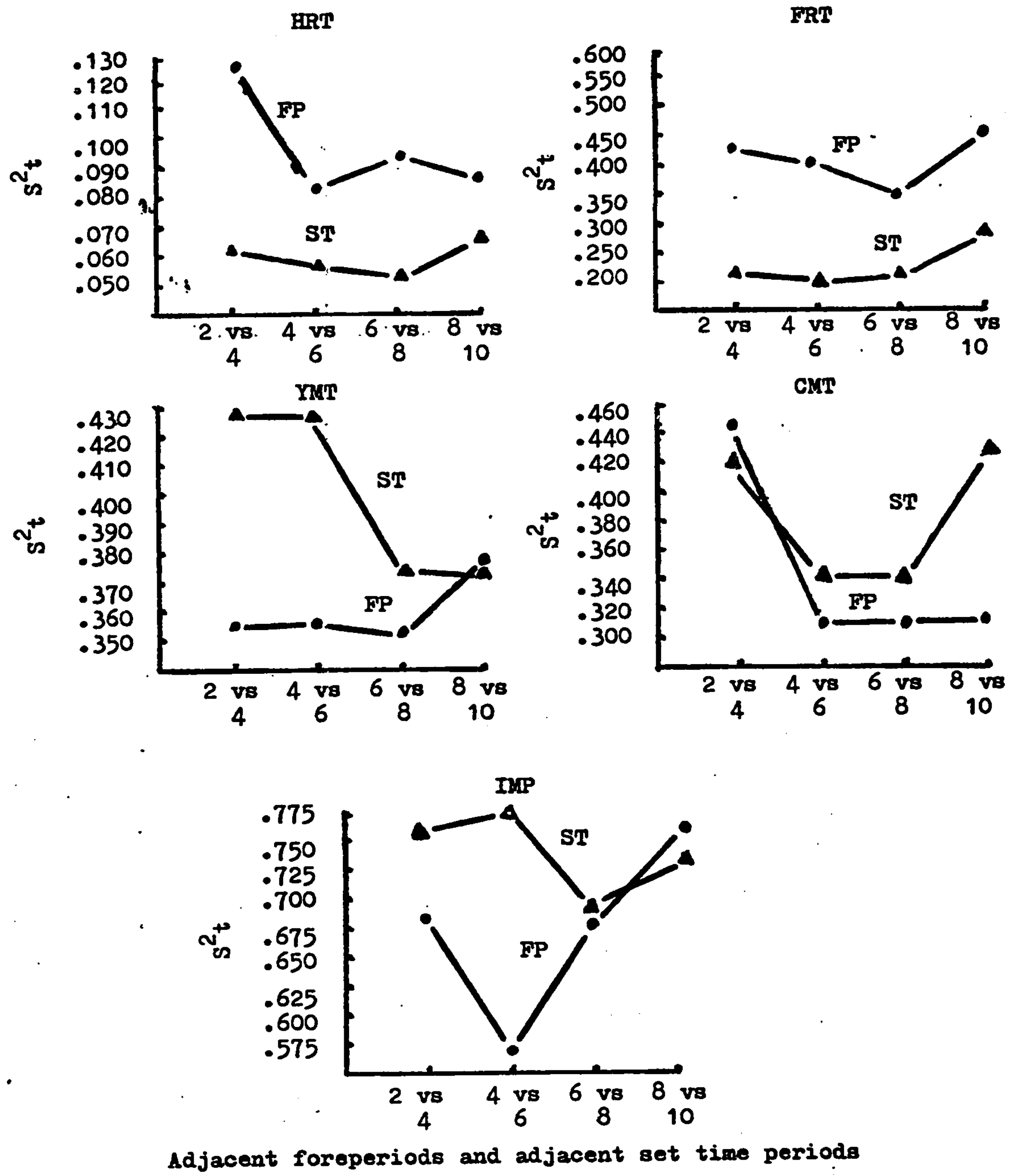


Figure # 7: True score variance between adjacent variable foreperiods and adjacent set time periods.

CHAPTER V

DISCUSSION

The purpose of study was to look at psychological and muscular readiness as factors which affect the reaction time, movement time, and force of movement of a whole body response task. It was hoped that such a study would give some indication of a subject's psychological and muscular preparation and his ability to maintain that readiness over a short duration of time. The foreperiod trials were designed to alter temporal uncertainty and thereby increase psychological uncertainty; and the set time trials, in which most of the psychological uncertainty was removed, purported to see whether or not muscular readiness factors alone were involved in response task performance.

COMBINED PSYCHOLOGICAL AND MUSCULAR READINESS

The results of the foreperiod trials not only supported much of the related literature, but also offered some new findings which should be considered.

Hand Reaction Time

The significant differences found for hand reaction time would seem to indicate a general trend toward a reduction of readiness as time passes during a foreperiod; and would therefore seem to support Karlin's (35), and Nickerson and Burnham's (51) results. However, it must be recognized also, that a second peak of performance was attained near the six second mark, and this indicates the attainment of a second readiness peak after a short period of lower readiness. Since the set time trials did not show similar trends, it can be concluded that the four second lapse and the six second recovery were due to psychological rather than muscular factors. There are two possible explanations for the peak-lapse-peak readiness trend. It is possible that the subjects were aware that as time passed, the stimulus became more and more probable. After the first few seconds, readiness dropped, but as time passed, the changing probability of termination produced a recovery of readiness. Once again, if there was no stimulus, readiness dropped off during the last four seconds of the foreperiod. The other possibility is that subjects developed modal foreperiods because of past experience in related tasks, and this possibility is further explored in a later section. In either case, it is evident that readiness for HRT could not be maintained into the latter stages of the foreperiod.

Foot Reaction Time

Although the only significant differences found for FRT were between the six and ten second foreperiods, inspection of the data revealed that the two second foreperiod was very close to the significance level also. Inspection also showed a general trend which resembled the findings for HRT. Although the readiness peaks appear at the two and six second foreperiods, there once again, is a general trend for readiness to remain fairly high for the first six seconds and then decline as the foreperiod approaches the ten second mark.

Once again, analysis of the set time trials show no similarity to the foreperiod trials as far as the six second peak is concerned. Since FRT was a measure of reaction time it would be expected that the same readiness peaks which affected HRT would have a similar effect on FRT.

Yard Movement Time

The F-ratio attained in the analysis of variance for yard movement time did not meet the minimum requirements for significance at the .05 confidence level. Thus, it appears that psychological readiness during a foreperiod has no bearing on a subject's ability to move quickly after he has initiated his whole body response movement. Since the YMT scores were much better for the ST trials than the FP trials, it appears that muscular factors have greater effect on movements than does psychological uncertainty. This is to be expected, because, by the time the actual YMT reading began, there was no longer any uncertainty as to when the stimulus would occur. The lack of significant differences in the YMT scores indicates that psychological factors can confound performance and it is possible, therefore, that muscular readiness is partially dependent upon psychological readiness.

Complete Movement Time

The complete movement time scores were found to contain significant differences, and it was observed that the graphed data closely paralled the results for HRT and FRT, but bore no resemblance to the graph of the YMT data. It appears therefore, that the same readiness peaks and loss of readiness are present in CMT as were found to be evident in HRT and FRT. It also seems that a quick start in a whole body response task is much more dependent on a fast reaction to a stimulus rather than a quick movement after the response has been initiated. The areas of statistically significant differences were not unexpected because CMT is a composite of HRT and YMT. Since no differences were found in YMT scores, it might be expected that CMT scores would parallel HRT scores, and this, in fact was found to be true.

Force x Time Integral (IMP)

Similar in nature to the HRT, FRT, and CMT data, the results of the impulse of movement data, indicate that the subjects prepared for a response at the two second mark, lost that readiness when no early stimulus appeared, and then began to develop further readiness for a foreperiod in the middle time duration range. Once again, it was evident that subjects were unable to maintain psychological readiness into the later stages of the trial period.

The higher impulse readings at the foreperiods which produced fastest reaction times are indicative of the nature of the force x time integral. Impulse is an inverse function of the time of force application, and therefore the shorter the time spent in the starting blocks, the greater the impulse.

Results and Previous Research

While the preceeding paragraphs have given some indication of what the results of the foreperiod trials show in terms of readiness for each aspect of performance, much more information was derived, and some interesting comparisons can be made between the results of this study and the findings of other researchers.

The HRT, FRT, and CMT data suggest that more than one psychological readiness peak can occur in a situation where randomized foreperiods are involved. The general trends, toward a decrease in HRT and FRT performance as a foreperiod ages, support the claims by Klemmer (37), Karlin (35), Botwinick and Thompson (7), and Nickerson and Burnham (51), that reaction time increases as the length of the foreperiod increases. Although the results did not follow an 'uninflected curve', as Karlin's did, the nature of the statistical findings serve to suggest that the subjects were unable to maintain peak readiness after approximately the six second foreperiod.

There may be varied reasons for this failure to remain ready. The subjects may simply have lost attention to the task because of the nature of the stressful set position they were in. In this case it is possible that muscular, rather than psychological, factors hampered performance. The results of the set time trials which indicate definite decreases in muscular readiness, make this possibility worth consideration.

Another possibility may have been the nature of the subject instructions and the resemblance of the set position to a track or football start. Since the subjects had been warned not to make a false start by moving before the arrival of the stimulus, it may have been that their attention to that admonition made them cautious of over-anticipation. If this actually happened, it would have had the same effect as the heads or tails type computer decision in the Nickerson and Burnham study (51). The effect of changing stimulus probability would have been reduced by the need to avoid error trials, and therefore there would not have been a heightening of readiness due to anticipation of a highly probable termination of foreperiod, during the final four seconds of the longer foreperiod time spans.

The final possibility is the chance that the subjects were unaware of the increasing probability of stimulus occurrence. It may simply have been that more temporal uncertainty was inherent in the long foreperiods, and that this reduced the subject's psychological readiness for reaction. This would seem to be the most likely cause of decreasing performance levels, because the studies by Karlin, Klemmer, and Botwinick and Thompson, did not involve a fatigue factor nor an avoidance of errors, and they found essentially the same results.

Despite the general trend for better performances to follow short foreperiods, it must be recognized that the data for HRT, FRT, CMT, and IMP showed a two peak readiness pattern. For each variable, the two second foreperiod performance was near the optimum, the four second performance was poorer, and then there was a second performance peak at the six second mark. Although this result was unanticipated, because of the warning against over-anticipation, it may be construed as evidence to support the five second optimum described by Teichner (64). Since Teichner's study also employed a muscular tension position during the foreperiod, it is possible that muscular readiness may have been involved and that muscular preparation peaks at about the five or six second mark. This however, was not found to be true in the set time trials where muscular readiness was of paramount importance and therefore, it would appear that the six second peak was due to psychological readiness.

As the foreperiod aged, the subjects may have anticipated a middle range termination, and therefore achieved the second readiness peak, and this could also have oocured in Teichner's study. However, because Teichner's subjects knew the time durations which he was using, they may not have anticipated short foreperiods. Since in the present study, the subjects did not know the foreperiod limits, and since they were instructed to prepare for response immediately upon assumption of the set position, it is possible that they achieved early readiness and then a second readiness peak as their anticipation increased. If this did happen, the reason may be found in the work of Drazin (16), Houle (29), and Zahn and Rosenthal (76). Houle found that in a varied foreperiod situation, reaction times decreased as foreperiod increased. Although this could explain the six second optimum, it does not explain the poorer scores at four seconds. Drazin, however, found that the subjects' expectations of foreperiod length were important in readiness, and Zahn and Rosenthal supported this. It is possible therefore, that most subjects anticipated a relatively short foreperiod. If a stimulus did not occur early, they became discouraged but then recovered as they began to feel that a stimulus was imminent. Once again, they lost attention if no stimulus arrived, and the second time, they were unable to prepare again. This type of sequential analysis would explain the foreperiod results. It seems possible that, although they were not part of the study, modal foreperiods such as those in Karlin's study (34), were developed by the subjects because of their naivity to the task and their adherence to the pre-test instructions regarding anticipation and errors.

Although Nakamura (48), Walker and Hayden (70) and Tuttle and Morehouse (69), all reported that starting 'speed' was affected by psychological readiness, it is apparent that they were not measuring movement speed but rather response speed. In each case they reported an optimum in the 1.5-2.0 second range. The results of this study do nothing to disprove those findings. Although YMT showed no significant performance peaks, it is evident that HRT, FRT, CMT and IMP were all at or close to peak performance at the two second foreperiod. Within the results of this study there did not seem to be a psychological readiness factor affecting speed of movement, and moreover, there was a low correlation between YMT and HRT and FRT. It seems that in a response movement, readiness is of most importance in obtaining fast reaction time.

Readiness also affected IMP in that peaks were found at the two and six second foreperiods. It seems therefore, that quickness of movement may breed power in the response, and simple physics formulae support this conclusion.[1]

MUSCULAR READINESS

It was assumed at the outset of the study that psychological readiness was not the only important factor in performance. Although few researchers have studied muscular readiness, logic suggests that if optimum performance in whole body response movement was desired, all the muscle groups involved in the movement must be ready to respond. To test this assumption, the set time trials employed a technique which, it was hoped, would eliminate psychological uncertainty by giving a forewarning of an impending stimulus. The warning allowed ample time for psychological preparation and should have brought anticipation and attention to the stimulus to a peak. It was reasoned therefore, that any change in performance must be muscular rather than psychological in origin.

Hand Reaction Time

The hand reaction time (HRT) results for the set time trials showed a definite trend toward better performance after the shorter time durations, and a gradual decrease in performance level as the set time ages. This indicates that an immediate build-up of readiness at the on-set of the stimulus occurs, and is followed by a gradual, progressive loss of muscular readiness as the set time period approaches the ten second mark.

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1 Since $S = 1/2\ at^2$ and $F = ma$, therefore: $S = 1/2 \frac{ft^2}{m}$

or $IMP = \frac{2\ Sm}{Time}$

These results suggest that when temporal uncertainty is relatively constant during each trial, the readiness in the responding muscle groups is dependent upon the length of time that the muscles have been held in a state of readiness. Although the scope of the study does not allow a conclusion concerning the reason for the loss in readiness, consideration of the events during the testing might shed light on this problem. The subjects were observed to begin showing overt signs of fatigue during the later stages of the longer set time periods. This fatigue was manifested in trembling of the support arm and a general trend toward rocking back out of the set position into a more relaxing squat-type stance. In many instances, it was apparent that subjects could not tolerate the fatiguing nature of the set position for a period of eight or ten seconds, and still maintain concentration on the task and attention to the stimuli.

Foot Reaction Time

Analysis of variance and subsequent Newman-Keuls analysis of the set time FRT scores, revealed the same trends in muscular readiness factors as were evident in the HRT trials. The subjects were able to prepare for about four seconds. However, they simply could not respond as quickly following long periods in a stressful set position as they could following the shorter periods. As was the case in the FP trials, these results were expected because FRT and HRT were both relative measures of reaction time. It is evident from the ST results that the same factors causing readiness peaks for HRT are also producing optimum FRT scores.

Yard Movement Time

Unlike the results for the foreperiod YMT scores, the set time YMT scores indicated that muscular readiness was definitely a factor in the speed of movement of a whole body response task. Short time durations produced near optimum movement, but as time in the stressful set position passed, the subjects were unable to move as quickly following their reaction to the stimulus. Although the curve of the scores is inflected in two places, a general trend toward poorer performance following the longer set time periods is evident.

The statistically significant differences in YMT further support the contention that muscular readiness is affected by the passage of time when the muscles are under stress. The lack of statistically significant findings in the FP trials indicates that readiness was confounded by temporal uncertainty. The increasingly poorer performance in the ST trials suggests that when psychological uncertainty is minimized, fatigue in the muscle groups involved in a response movement can cause an appreciable decrease in muscular readiness.

Complete Movement Time

Since the CMT scores are a composite of the HRT and YMT scores, the magnitude of the F-ratio (17.9) might possibly be explained by the fact that the F-ratios for both HRT and YMT were significant and fairly high. The indications, once again, are that muscular readiness for a response plus movement type task, is at a high point early in the set time, and falls off to a low point as the set time period ages and subject either becomes fatigued or unable to maintain muscular tension.

Force x Time Integral (IMP)

The better scores in the set time trials indicate that the warning signal actually did accomplish its task of reducing the psychological uncertainty. There remains however, evidence that muscular readiness is also important. The general decreases in IMP as set time increases, shows that the powerful extensor muscles of the hip and knee are not as ready for a quick response movement following longer periods in a stressful set position as they are after short set time periods. Muscular readiness peaks before the two second mark, and cannot be held at a peak much past that two second optimum.

Results and Previous Research

The results of the set time scores for HRT, FRT, CMT, YMT, and IMP, all show that level of performance declined as the set time period aged. Therefore, muscular readiness was at a peak at the beginning of the set time and decreased as time passed. This decline could be attributed to the nature of the subject instructions which demanded immediate preparation upon assumption of the set position, and also to the contention that to maintain readiness, a subject must use progressively more voluntary effort as time passes (40). If the subjects had to use progressively more voluntary effort, it could be that they would not have enough readiness left to perform maximally. The results also supported Tuttle's statement (68) that maximum tension was held only momentarily before fatigue began to set in. Informal post-test questioning of the subjects revealed that in most cases, the subject began to feel a strain on his legs and support hand and this may have been an indication of either greater effort on the subject's part to remain ready, or the onset of fatigue in the tensed musculature.

Maugdil and Karpovich (46) and Hettinger (27) reported that force in the musculature began to decline as early as 2.6 seconds (46) and definitely within the first ten seconds (27). These findings are supported by the results of all of the mean test scores in the set time trials. Although the CMT curve (Figure 4) was the only one uninflected, each of the plotted curves (Figures 2-6) showed that muscular readiness was at a peak at the two second mark. The HRT and FRT results showed readiness remaining until about the four second mark, but the overall results seemed to indicate a decreasing readiness and therefore poorer performance, as the set time period grew longer.

Since there was no direct measure of muscular tension, it is difficult to relate the results to studies which have taken such measures. However, Kagan's hypothesis, that muscular readiness involves a build-up of muscular tension (33), can be applied. In this study, the subjects were in a tensed position and were ready to respond until about the four second mark; after that their readiness fell off, and this could be an indication of decreased tension, fatigue, or voluntary relaxation due to the stress of the set position and the lack of a stimulus. If tension is the critical factor, it appears that Kagan's view was closer to being correct than was Davis (14), who said that muscular tension underwent a slow, gradual build-up to a maximum. However, the poorer scores at the longer foreperiods in the present study do not support Davis' contention.

Despite varying degrees of agreement with some of the related research, some definite facts concerning muscular preparation and readiness for a whole body reaction-movement task were evident. The subjects were able to prepare early and to hold readiness for approximately four seconds. After the four second mark, readiness dropped and performance level declined. Also apparent was the fact that muscular readiness was a factor in performance even when psychological readiness was attained through knowledge of when the stimulus was to occur.

SUPPORT OF HYPOTHESES

In terms of the null hypothesis, which stated that neither foreperiod (temporal uncertainty) nor set time (muscular readiness factors) affected reaction time, movement time, or force of movement, a rejection can be made at the 95 % level of confidence. It is therefore possible to accept most of the implications of the research hypotheses and draw the following conclusions:

(1) With the exception of a six second readiness peak, reaction time increases as the foreperiod ages in a variable FP event.

(2) Although there is no appreciable difference between two and four second trial scores, reaction time tends to increase as the time in a set position increases.

(3) Temporal uncertainty during a preparatory interval has no significant effect on movement time.

(4) Movement time is slower following long periods in a set position than following shorter periods of up to six seconds.

(5) Foreperiod aging caused a general decrease in the impulse of the reaction, although a second readiness peak occurred at the six second mark.

(6) A subject is unable to react with as much movement impulse as a result of spending progressively more time in a stressful set position.

As a result of the rejection of the null hypothesis and the formation of the above conclusions, it is possible to draw overall conclusions concerning readiness for response. While a combination of psychological uncertainty and lack of muscular readiness seems to decrease performance more than muscular factors alone, it must be realized that muscular readiness is also important in the preparation for a maximal response movement. Therefore, it may be concluded that the characteristics (HRT, FRT, YMT, CMT, IMP) of a response movement are dependent upon both psychological and muscular preparation and readiness for performance at a maximum level.

COMBINED MUSCULAR-PSYCHOLOGICAL VERSUS MUSCULAR READINESS

Although the temporal uncertainty trials served as evidence that the combined effects of psychological and muscular readiness factors had greater effect on performance than muscular factors taken alone, it is of interest to note the differences between the two types of readiness.

For each dependent variable it can be readily observed that in no set of trials were the foreperiod scores better than the set time scores, and in all but three of twenty-five cases, significant t-ratios were found ($P < .05$, 23) for set time versus foreperiod trials. This not only indicates a greater combined effect of psychological and muscular factors, but also it shows that the warning signal in the set time trials provided enough information and enough time to allow psychological preparation.

The double peaking effect in the foreperiod trials shows that psychological readiness can and does occur at more than one point. The degree of expectancy may have been a factor in these results in view of the athletic background of many of the subjects. Since most of the subjects indicated experience at starting out of a whole body set position, either in football or track competition, it is reasonable to expect that they were accustomed to relatively short 'set' periods. When an early stimulus did not arrive, they relaxed or gave up, but then realizing that a stimulus had to come soon, they were able to prepare a second time for a middle range termination. If a stimulus did not appear at this second point of expectation, readiness once again fell off, and was not regained.

If Lippold's hypothesis (40), that it takes progressively more effort to maintain muscular readiness is true, it is logical to anticipate only one muscular readiness peak near the beginning of the time in set position. This was found to be the case, in the results for each of the performance factors in the set time trials. No marked points of inflection were found in the trends for performance scores to be progressively poorer as the set time ages. Thus, it would appear that the subjects were able to develop maximum muscular readiness in somewhat less than two seconds, and that almost immediately, they either began to lose muscular tension, or fatigue began to set in. If a similar study were designed to use electromyographic techniques to measure muscle action potentials during the set time period and response movement, it might be possible to further evaluate the effects of muscular preparation, and to more fully understand and explain the nature and components of muscular readiness. Until that type of study is completed, it must suffice to say that during a time in a set position, muscular readiness undergoes a progressive deterioration as the set time passes.

APPLICATIONS

The results of the study suggest several implications for performance of whole body reaction movements, such as are important in many sport and human performance situations. For several reasons, coaches and performers should take note of readiness factors in both training sessions and competitive performance. For example, knowledge of maximum readiness and when it occurs could help a performer to ensure that he was adequately prepared, and it could also aid in the development of strategy designed to decrease an opponent's readiness.

The foreperiod situation employed in this study is somewhat analogous to a defensive football situation in which the linemen assume a set stance before the offense is set. The results of the HRT, FRT, CMT, and IMP scores indicate that as little time as possible should be spent in the set position, if the fastest and most explosive response is desired. It would therefore be wise for a defensive coach to instruct his players to remain standing and relaxed until the offensive line began to go down. On the other hand, the offensive team might wish to induce more uncertainty and muscular fatigue by extending the count and keeping the defense down as long as possible. However, the set time data for HRT, FRT, and IMP suggest caution against too long a set period even for the offense, because even when the subjects knew when the stimulus was to come, they could not perform as well following a longer set time. Evidence shows that FP trials gave poorer performance that ST trials and therefore, if a coach is willing to sacrifice some mobility in his offensive line, he should probably use a long count because psychological plus muscular unpreparadness overbalance lack of muscular readiness in its effect on the response time, movement time and force of a whole body movement.

The results also verify the findings by Nakamura (48), Walker and Hayden (70), and Tuttle and Morehouse (69), that short foreperiods generally produce best performance. Although two seconds was the shortest FP and ST used, it seems that in most cases, readiness was at a definite peak, and then fell off sharply at 4 seconds. Although the nature of the study does not allow a definite conclusion in this regard, it appears that in a controlled foreperiod event such as a track or swimming start, a set period in the 1.5 to 2 second range is optimum.

The advantage for a baseball batter who assumes a rigid position of steadiness and concentration prior to each pitch is questionable. The batting situation is analogous to the set time trials of this study. The batter tenses, and awaits the warning that movement is about to be required. The release of the ball corresponds to the warning, and a short time later, movement must begin. The poorer performances in HRT, FRT, CMT, and IMP following set times of six, eight, and ten seconds, suggests that even when a batter has to react only after a type of prewarning signal, he should not steady the bat and prepare muscularly until the pitcher is well into the final stages of his pitching motion.

This same type of analogy occurs in racquet sports such as badminton and tennis, where a player awaiting a serve assumes a tensed ready position. Although he sees the serve being executed, he may not be able to react quite as fast or as forcefully as possible, if he has spent more than about two to four seconds in a tensed position.

Although several other performance situations are affected by readiness factors, the cases cited seem to be representative of the general nature of reaction movement. Within the bounds of the study, the evidence suggests that regardless of whether or not the situation involves temporal uncertainty and unexpected stimuli, total readiness is seldom maintained beyond four or six seconds, and is generally at a peak during the early stages of the foreperiod or set time situation.

GENERAL DISCUSSION

During the execution of the study, several factors of importance became apparent. Some of these imposed limitations while others seemed beneficial to the research and its intended purpose.

The nature of the set position and its resemblance to a three point football stance, seemed to help the subjects become familiarized with the research task; and, it also seemed to motivate them to perform maximally because of their knowledge of the necessity of a fast and forceful response in the performance of such a task. It was however, difficult to ensure that each subject kept his stance precisely the same on each of the trials, and therefore, to a slight degree, stance variation could have confounded the intra-individual variation. Also, although nearly all subjects indicated a feeling of stress on the hip and leg muscles, some of the heavier subjects also mentioned a fatiguing of the support arm and this may have been a source of some of the variance within subjects.

Although there was some apprehension over the use of planimetry to determine the force x time integrals of the impulse curves, it would appear that if certain precautions are taken, and adequate training is undertaken, this is a viable method of extracting desired data from chart graphs. The method, however, is fairly time consuming, and in this respect it does impose limitations on the scope of a study. If it was necessary to test a large number of subjects in a number of test conditions, there would be obvious advantages in the use of an 'on line' system which would give an immediate measure of the integral score on each trial.

In spite of the presence of some psychological uncertainty, and the necessity to predict a one second time lapse, it is apparent that the methodology of the set time trials did effectively increase psychological readiness, and therefore, allowed a study of the effects of muscular readiness factors on performance. The effectiveness of the one second warning was further reinforced by observation of the testing. In nearly every case, the subjects showed overt signs of anticipation and attention to the stimulus following the warning signal, and yet their performance was poorer following the longer time periods. In retrospect, it would seem that such a method provides a simple yet effective way of measuring muscular readiness.

In terms of muscular readiness, the study is limited by the fact that it is still difficult to define muscular readiness. A follow-up study using a technique such as Teichner's (64), but incorporating the warning signal trials rather than a foreperiod situation, could be valuable in relating muscular readiness to tension level. Another important step that could be taken is the incorporation of electromyographic techniques into a study designed to look at muscular readiness as a factor in performance.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of the research was to study the effects of psychological and muscular readiness on the performance of a whole body response task. A foreperiod situation was employed as a means of altering the psychological preparation, and a set time situation was used as a gauge of muscular preparation. A three point stance and a foreward charge out of a set of starting blocks, which contained a strain gauge transducer system, were used as the set position and research task respectively.

Twenty-four subjects were selected from among the physical education students at the University of Windsor, and each was tested twice under each of the two readiness conditions. Measurements were taken of the following characteristics of performance: (a) the time between stimulus and first overt movement of the support hand (HRT); (b) the time between stimulus and first horizontal force exertion by the left foot (FRT); (c) the time following the HRT for the subject to move one yard foreward (YMT); (d) a combined measure of HRT and YMT (CMT); (e) a measure of the force x time integral or impulse of the horizontal force exerted by the left foot against the starting block strain gauge.

Conclusions

The data extracted was analyzed by means of one way analysis of variance with repeated measures, and Newman-Keuls analysis, and within the confines of the study, the null hypothesis was rejected ($P < .05$) and the following conclusions derived.

(1) Combined psychological and muscular readiness peaks early in the foreperiod, and if no stimulus arrives, readiness wanes.

(2) As a foreperiod ages, psychological readiness may peak a second time if the subject anticipates termination at a particular time.

(3) Combined psychological and muscular readiness shows a tendency to decrease as a foreperiod ages, and there is significantly less readiness at longer time durations than at shorter ones.

(4) Muscular readiness is also an important factor in an optimum whole body response movement.

(5) Muscular readiness is held at an optimum for about the first four seconds of set time, and then a progressive decrease is evident as the set time period ages.

(6) It appears that after muscular readiness reaches a peak and then declines, it is difficult to achieve a second muscular readiness peak.

(7) Variance in reaction time, movement time, and impulse is not due to common factors.

(8) Readiness factors (i.e. variable FP and ST), do not affect individual differences in a consistent manner.

(9) The effect of a variable foreperiod on performance of a whole body response task is significantly greater than the effect of a low temporal uncertainty, set time period.

In all cases except FP YMT, analysis of variance showed significance at less than the .05 level of confidence. This indicates that both psychological and muscular readiness play important roles in the formation of an optimum whole body response movement.

Further Direction

As the study progressed and the results became known, obvious needs for further research became apparent. There should be similar research done, using a wider range of time durations and smaller intervals. This would more accurately determine the ability to achieve subsequent readiness peaks after the first peak of preparation has been lost. A study designed to employ modal foreperiods might provide further information regarding the effects of expectancy and anticipation on psychological readiness. Finally, if a study could be designed which employed a whole body response, but not a stressful set position, more information concerning the psychological readiness curve could be found because muscular strain and fatigue would not be factors.

The area demanding the most attention in preparatory set for whole body movement is muscular readiness. The most obvious step is to determine what muscular preparation involves. A study in which pre-tensed and pre-relaxed voluntary control is used in a set time period situation, might give some indication as to which factor is the most important in readiness. More studies similar to Teichner's (64), in which various tension loads are used in a forepriod and also a set time situation, would be helpful in determining whether or not greater levels of tension affected performance in either of a psychologically uncertain or a psychologically certain situation. Finally, work in electromyography could determine the various levels of tension and fatigue by studying the electrical potentials of the synergistic muscle groups which are under strain in a preparatory set position.

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APPENDIX A

APPARATUS

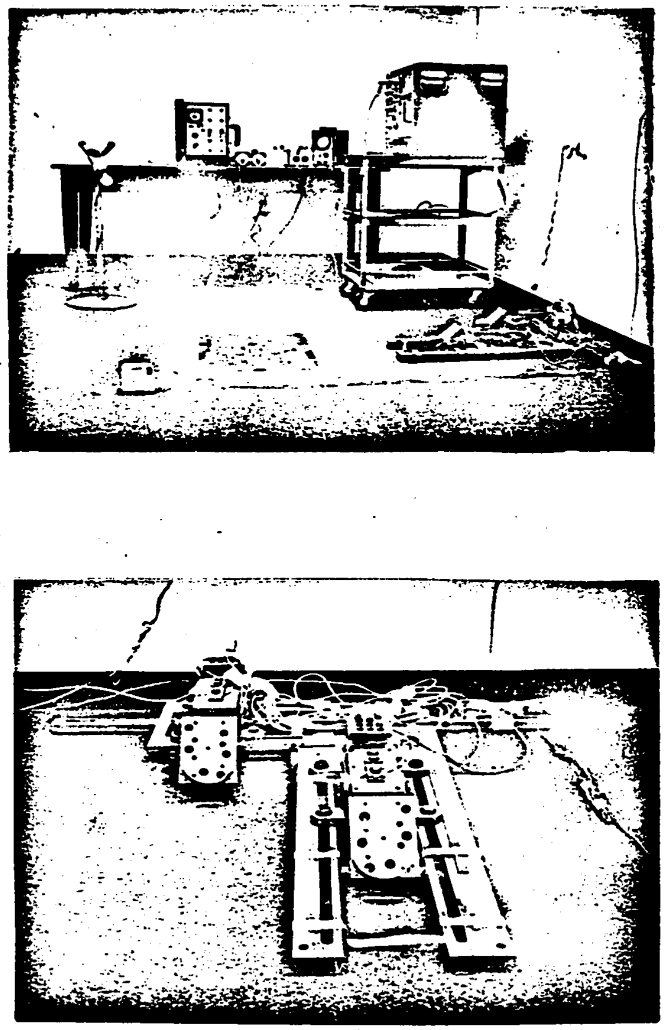
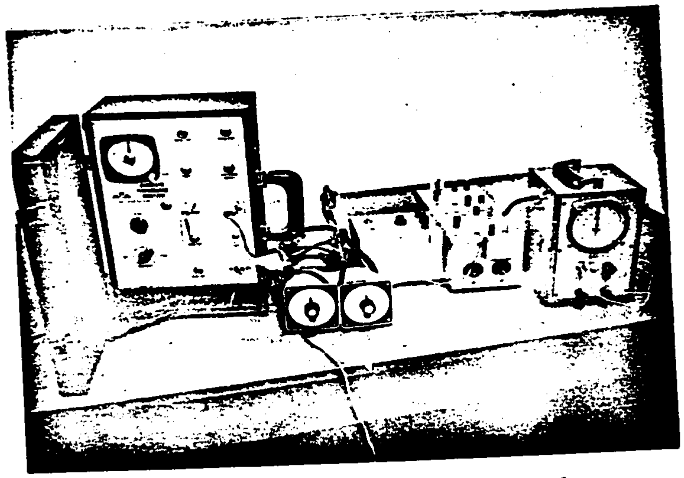


Figure 8. Apparatus.



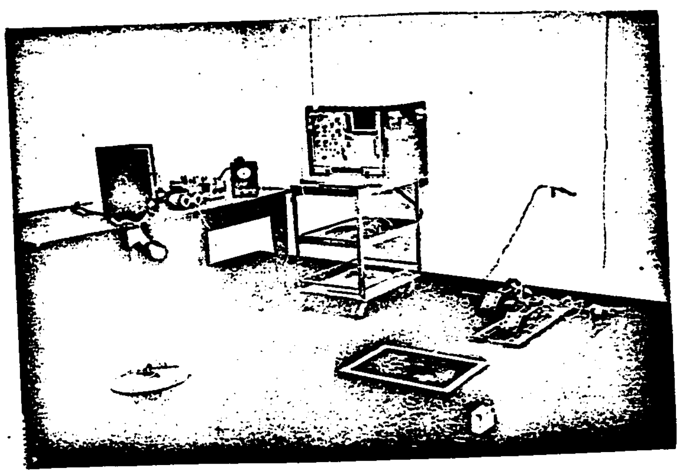


Figure 9. Apparatus.

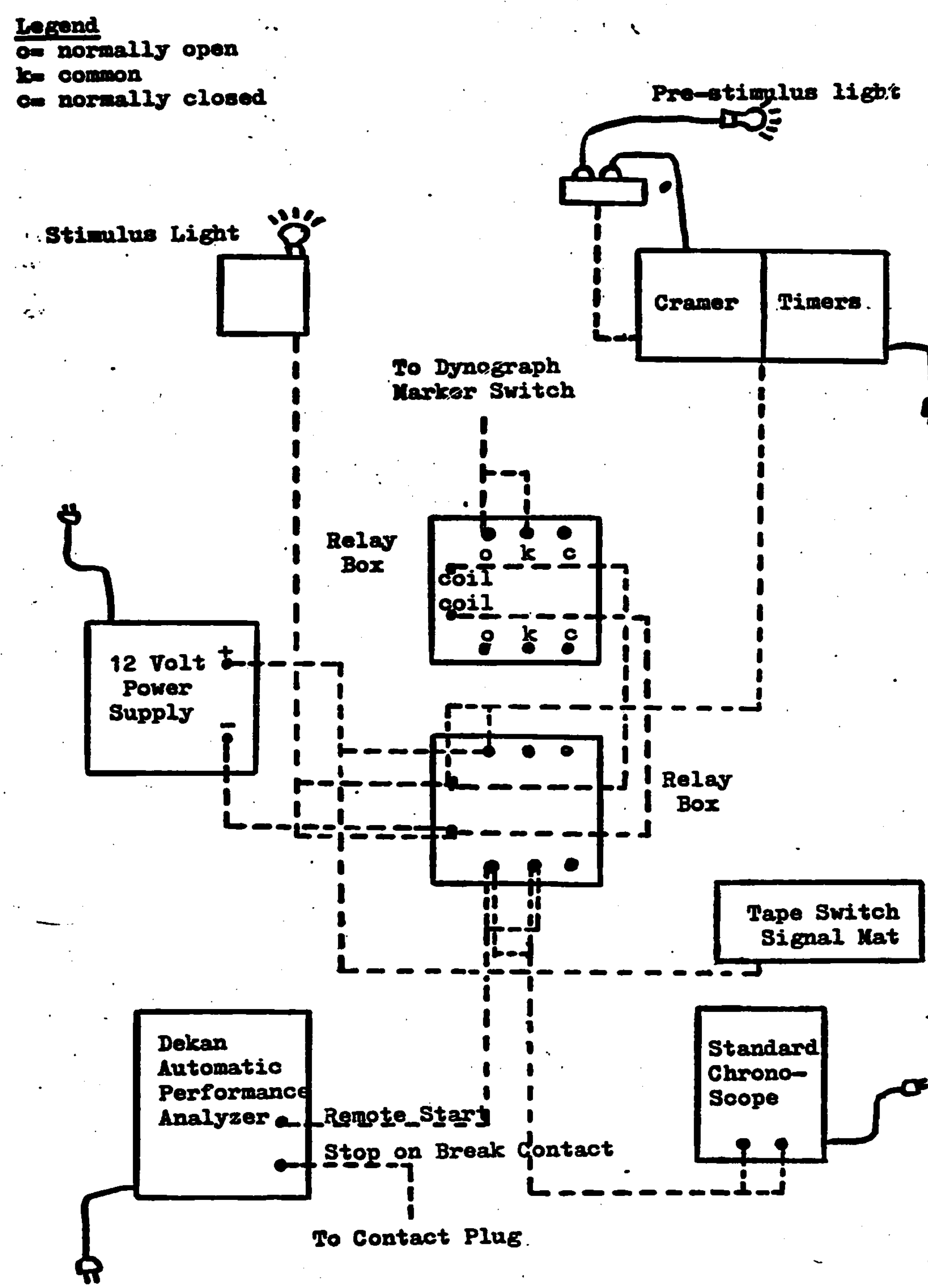
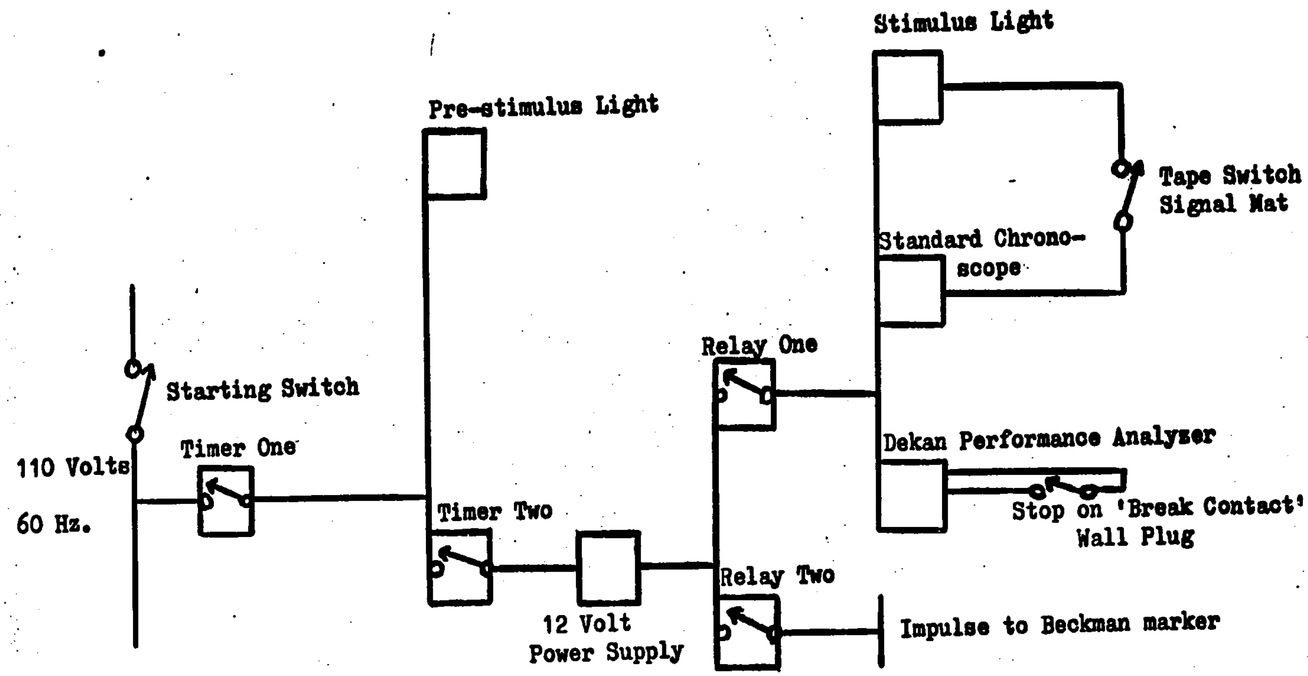


Figure 10. Electrical Apparatus



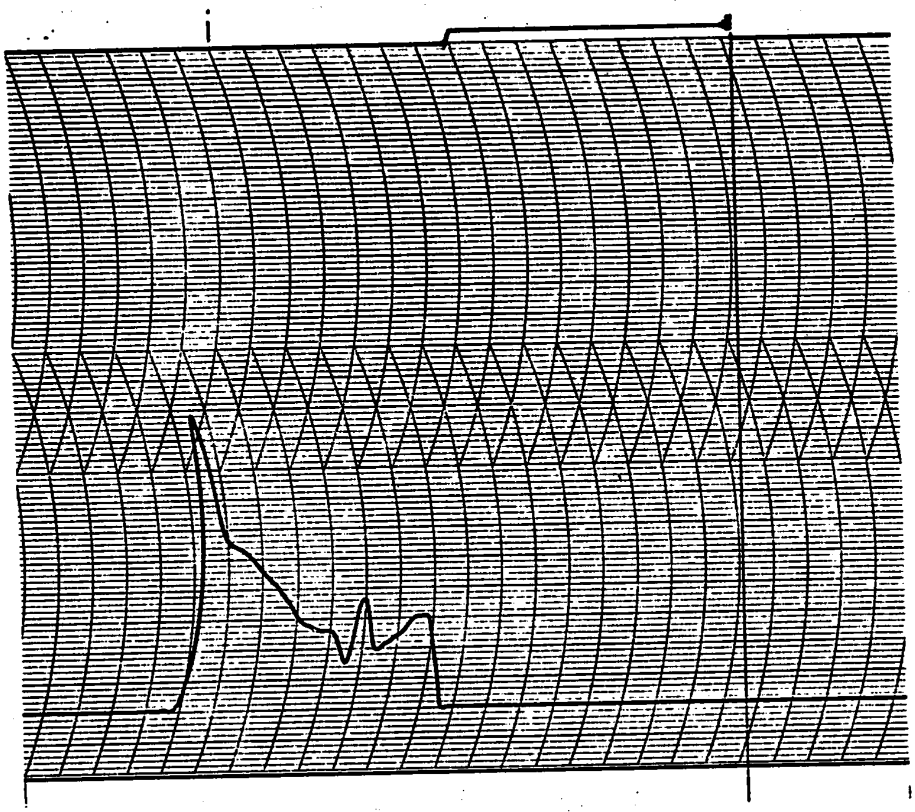
Closure of Researchers switch sends power to timer 1 which times out and closes an internal switch.

Closure of timer 1 switch sends power to timer 2 and the pre-stimulus light.

Closure of timer 2 switch sends power to the 12 volt supply which in turn closes the normally open switches in both relays.

The closure of the relay switches simultaneously starts the stimulus light, the standard chronoscope, and the performance analyzer. Also, the Beckman paper is marked to indicate the onset of the stimulus.

Figure 11. Apparatus: Electrical Sequence



Impulse (force x time integral) was found by measuring the area under the force curve.

Foot Reaction Time was found by measuring the distance from the mark indicating the onset of the stimulus to the point of first application of force by the left foot and leg.

Figure 12. Typical Beckman print out of Force-time curve.

APPENDIX B

DATA

TABLE XXXIII

MEAN HAND REACTION TIME FOLLOWING
FIVE FOREPERIODS
(seconds)
(N=24)

Subject	Foreperiod (in sec.) 2	4	6	8	10
1	.2479	.2756	.2559	.2873	.2835
2	.2463	.2560	.2455	.2561	.2693
3	.2472	.2880	.2906	.3165	.3152
4	.2615	.3128	.3234	.3324	.3666
5	.3143	.3095	.2939	.3376	.3021
6	.4507	.3545	.2900	.3486	.2974
7	.2377	.2413	.2527	.2759	.2657
8	.2348	.2533	.2401	.2470	.2881
9	.2346	.2136	.2176	.2115	.2071
10	.2496	.2775	.2598	.2919	.2822
11	.2103	.2213	.2304	.2722	.2644
12	.2817	.2847	.2458	.3007	.3028
13	.2544	.3045	.2559	.2761	.3132
14	.2702	.2681	.2769	.2872	.2684
15	.2797	.2901	.2962	.2810	.3182
16	.2583	.2905	.2487	.2664	.2812
17	.3024	.3496	.3283	.3246	.3610
18	.2551	.2674	.2689	.2942	.2870
19	.2610	.3122	.2318	.2549	.2647
20	.3227	.3325	.3289	.3744	.3923
21	.2233	.2515	.2424	.2684	.2649
22	.2551	.3216	.2809	.3078	.3386
23	.2657	.2861	.2572	.2925	.3652
24	.2203	.2388	.2065	.2170	.2740
Mean	.2661	.2845	.2656	.2910	.3018

TABLE XXXIV

MEAN FOOT REACTION TIME FOLLOWING
FIVE FOREPERIODS
(seconds)
(N=24)

Subject	Foreperiod (in sec.) 2	4	6	8	10
1	.287	.307	.272	.305	.314
2	.254	.278	.240	.249	.265
3	.268	.283	.331	.267	.320
4	.308	.328	.342	.325	.393
5	.162	.197	.165	.270	.238
6	.429	.365	.298	.394	.350
7	.334	.376	.339	.348	.359
8	.261	.271	.232	.267	.302
9	.308	.304	.287	.305	.327
10	.231	.286	.274	.273	.284
11	.204	.216	.198	.222	.224
12	.326	.297	.218	.283	.330
13	.188	.144	.188	.189	.227
14	.203	.221	.191	.268	.215
15	.211	.373	.327	.281	.307
16	.183	.178	.161	.161	.185
17	.243	.242	.282	.246	.276
18	.254	.300	.256	.269	.287
19	.401	.464	.351	.555	.422
20	.306	.341	.371	.427	.443
21	.287	.307	.272	.305	.314
22	.287	.307	.272	.305	.314
23	.311	.372	.247	.355	.423
24	.409	.328	.342	.334	.349
Mean	.283	.304	.273	.305	.317

TABLE XXXV

MEAN YARD MOVEMENT TIME FOLLOWING
FIVE FOREPERIODS
(seconds)
(N=24)

Subject	Foreperiod (in sec.) 2	4	6	8	10
1	.5046	.5154	.4885	.5192	.4885
2	.4172	.4215	.4094	.4128	.4007
3	.4463	.4124	.4033	.3925	.3757
4	.3810	.3213	.3501	.3456	.3399
5	.2997	.3134	.3225	.3164	.3394
6	.4318	.4340	.4555	.4564	.4481
7	.5207	.5336	.5078	.5111	.5183
8	.5102	.4842	.5094	.4595	.5601
9	.4949	.4574	.4728	.4567	.4695
10	.4649	.4366	.4514	.4486	.4138
11	.4280	.4317	.4071	.4028	.4276
12	.4093	.3962	.3852	.3903	.4252
13	.3631	.3875	.3941	.4484	.4008
14	.3728	.3664	.3616	.3658	.3596
15	.4623	.4039	.4018	.3950	.3842
16	.2967	.2701	.2593	.2731	.3068
17	.3725	.3409	.3817	.3699	.3690
18	.4314	.4436	.4205	.4137	.4350
19	.5379	.5728	.5128	.5431	.5773
20	.3613	.3325	.3289	.3746	.3923
21	.3822	.3740	.3826	.3781	.4081
22	.4039	.3284	.3706	.3587	.3729
23	.3628	.3984	.3553	.3715	.3858
24	.3917	.3947	.4285	.4029	.3990
Mean	.4186	.4071	.4067	.4086	.4165

TABLE XXXVI

MEAN COMPLETE MOVEMENT TIME FOLLOWING
FIVE FOREPERIODS
(seconds)
(N=24)

Subject	Foreperiod (in sec.) 2	4	6	8	10
1	.752	.791	.744	.806	.673
2	.644	.678	.655	.669	.670
3	.694	.700	.694	.709	.691
4	.643	.634	.674	.678	.709
5	.614	.623	.617	.654	.642
6	.883	.788	.745	.805	.746
7	.758	.775	.761	.786	.784
8	.745	.733	.750	.757	.811
9	.730	.699	.697	.730	.747
10	.715	.714	.711	.741	.696
11	.641	.653	.638	.680	.694
12	.691	.681	.631	.691	.728
13	.618	.633	.650	.624	.614
14	.643	.635	.639	.653	.628
15	.692	.694	.708	.676	.703
16	.555	.550	.558	.540	.538
17	.673	.606	.710	.695	.730
18	.688	.711	.690	.708	.722
19	.799	.885	.744	.794	.842
20	.684	.702	.693	.730	.668
21	.606	.626	.626	.647	.667
22	.659	.650	.654	.664	.712
23	.629	.685	.613	.664	.751
24	.612	.636	.635	.620	.673
Mean	.683	.687	.677	.697	.702

TABLE XXXVII

MEAN FORCE X TIME INTEGRAL FOLLOWING FIVE FOREPERIODS (seconds) (N=24)

	Foreperiod (in sec.)				
Subject	2	4	6	8	10
1	133	133	143	115	124
2	96	81	104	96	90
3	110	101	105	96	90
4	107	99	97	98	103
5	128	139	126	126	128
6	106	95	96	89	77
7	70	52	74	63	62
8	90	101	98	77	88
9	63	66	68	73	57
10	125	97	112	126	110
11	111	114	89	94	85
12	141	121	137	117	123
13	90	96	113	89	68
14	142	108	136	126	139
15	91	73	112	131	112
16	123	129	122	116	128
17	67	58	60	77	64
18	96	91	126	99	96
19	86	71	88	25	85
20	80	82	90	54	49
21	144	125	122	110	87
22	119	114	122	127	120
23	63	59	80	56	53
24	31	48	46	38	42
Mean	101	94	103	93	91

TABLE XXXVIII

MEAN HAND REACTION TIME FOLLOWING
FIVE SET TIME PERIODS
(seconds)
(N=24)

Subject	Set Time (in sec.) 2	4	6	8	10
1	.2907	.2685	.2509	.3045	.3110
2	.2767	.2796	.2599	.2573	.2715
3	.2248	.2203	.2584	.2455	.2433
4	.2674	.2297	.2645	.2855	.2660
5	.2848	.3000	.2953	.2811	.3468
6	.2378	.2432	.2519	.2504	.2306
7	.2010	.2149	.2191	.2216	.2735
8	.2296	.2136	.2176	.2115	.2971
9	.2434	.2298	.2431	.2257	.2386
10	.2222	.2218	.2400	.2941	.3130
11	.2206	.2197	.2197	.2777	.2760
12	.2357	.2409	.2443	.2300	.2707
13	.1939	.2387	.2136	.2182	.2284
14	.2395	.2310	.2407	.2436	.2237
15	.2690	.2486	.2770	.2784	.3139
16	.2257	.2217	.2363	.2449	.2616
17	.2308	.2154	.2360	.2628	.2578
18	.2190	.2235	.2335	.2517	.2630
19	.2208	.2312	.2508	.2686	.2462
20	.2852	.2954	.3051	.2944	.3267
21	.2339	.2450	.2566	.2392	.2861
22	.2377	.2415	.2462	.2516	.2516
23	.2086	.2222	.2293	.2487	.2646
24	.1998	.1942	.1954	.2202	.2055
Mean	.2374	.2371	.2452	.2545	.2657

TABLE XXXIX

MEAN FOOT REACTION TIME FOLLOWING
FIVE SET TIME PERIODS
(seconds)
(N=24)

Subject	Set Time (in sec.) 2	4	6	8	10
1	.234	.227	.242	.253	.254
2	.246	.234	.238	.274	.229
3	.180	.168	.257	.217	.220
4	.240	.211	.235	.267	.250
5	.164	.152	.162	.147	.156
6	.249	.291	.258	.272	.268
7	.248	.262	.252	.289	.275
8	.285	.220	.230	.207	.242
9	.260	.263	.307	.317	.319
10	.227	.222	.237	.296	.302
11	.194	.223	.264	.255	.214
12	.246	.217	.224	.212	.257
13	.163	.219	.183	.193	.179
14	.164	.174	.205	.190	.140
15	.259	.259	.278	.283	.317
16	.141	.135	.149	.225	.146
17	.243	.242	.282	.246	.276
18	.238	.203	.198	.230	.225
19	.411	.351	.407	.426	.441
20	.286	.276	.265	.276	.365
21	.234	.227	.242	.253	.254
22	.234	.227	.242	.253	.254
23	.246	.217	.237	.250	.292
24	.228	.231	.220	.255	.234
Mean	.234	.227	.242	.254	.255

TABLE XL

MEAN YARD MOVEMENT TIME FOLLOWING
FIVE SET TIME PERIODS
(seconds)
(N=24)

	Set Time (in sec.)				
Subject	2	4	6	8	10
1	.5233	.5564	.4741	.4875	.5400
2	.4122	.4024	.3941	.4182	.4364
3	.3372	.3486	.3635	.3895	.3707
4	.3625	.3523	.3535	.3540	.3390
5	.2976	.3019	.2822	.3209	.2657
6	.4382	.4603	.4446	.4596	.4919
7	.4309	.4351	.4384	.4554	.4240
8	.4644	.4784	.5009	.4655	.4699
9	.3966	.4287	.4264	.5022	.4774
10	.4613	.4647	.4679	.4759	.4360
11	.4131	.4361	.4373	.4828	.4380
12	.3853	.3826	.3767	.3920	.4048
13	.3931	.4038	.3994	.3943	.3926
14	.3385	.3330	.3398	.3555	.3513
15	.3705	.3904	.3960	.3906	.4052
16	.2833	.2612	.2597	.2736	.2829
17	.3611	.3721	.3790	.3591	.3722
18	.3640	.4089	.3705	.3908	.3745
19	.5062	.4488	.4922	.4660	.5253
20	.3658	.3706	.3699	.3786	.3748
21	.3976	.3850	.3634	.4038	.3939
22	.3428	.3475	.3147	.3494	.3402
23	.3174	.3468	.3472	.3513	.3409
24	.3702	.3503	.3705	.3569	.3550
Mean	.3889	.3944	.3901	.4031	.4001

TABLE XLI

MEAN COMPLETE MOVEMENT TIME FOLLOWING
FIVE SET TIME PERIODS
(seconds)
(N=24)

Subject	Set Time (in sec.) 2	4	6	8	10
1	.814	.824	.725	.792	.851
2	.689	.682	.654	.675	.708
3	.562	.569	.622	.635	.614
4	.630	.582	.618	.640	.695
5	.582	.602	.578	.602	.658
6	.675	.704	.697	.710	.723
7	.632	.630	.658	.687	.698
8	.694	.692	.719	.677	.675
9	.640	.659	.670	.727	.716
10	.684	.687	.708	.770	.749
11	.624	.654	.659	.761	.714
12	.621	.624	.621	.622	.674
13	.587	.643	.613	.613	.621
14	.578	.564	.579	.599	.575
15	.640	.639	.673	.669	.720
16	.509	.483	.496	.519	.544
17	.592	.588	.615	.622	.630
18	.583	.633	.604	.652	.638
19	.727	.680	.743	.735	.772
20	.651	.666	.675	.673	.701
21	.631	.630	.620	.643	.680
22	.581	.589	.561	.601	.595
23	.526	.569	.577	.600	.606
24	.570	.545	.566	.577	.560
Mean	.626	.631	.635	.658	.672

TABLE XLII

MEAN FORCE X TIME INTEGRAL FOLLOWING
FIVE SET TIME PERIODS
(seconds)
(N=24)

Subject	Set Time (in sec.) 2	4	6	8	10
1	116	110	133	107	117
2	123	129	111	100	121
3	118	109	87	88	113
4	105	99	97	92	102
5	140	135	134	139	133
6	92	85	85	78	76
7	74	50	67	60	67
8	110	95	88	91	80
9	80	81	56	83	70
10	188	158	156	139	165
11	101	89	100	81	80
12	149	148	147	136	148
13	97	90	100	72	87
14	137	141	133	148	155
15	151	137	149	139	141
16	126	133	125	111	120
17	91	73	77	85	73
18	121	127	118	87	105
19	110	87	106	99	75
20	89	96	74	84	73
21	132	147	148	118	131
22	143	132	137	119	111
23	82	59	84	68	62
24	79	89	72	60	68
Mean	115	108	107	99	103

APPENDIX C

SUBJECT INSTRUCTIONS

SUBJECT INSTRUCTIONS: FOREPERIOD TRIALS

1. On each trial you will take a preparatory position with your feet resting on the starting block apparatus.

2. When you are ready, assume your set position by placing your right hand on the X mark on the tape switch signal pad.

3. As you assume your set position you will hear the verbal command READY, at which time you must immediately prepare for a possible stimulus presentation.

4. When the stimulus light does come on, you are to charge foreward in a running start and sprint to the tape line on the floor. Continue to accelerate until you have crossed the finish line.

5. You MUST perceive a stimulus light before you react. Any false start trial will be invalidated and will be repeated at a later time.

6. A Maximum effort is mandatory on every trial.

7. Measurements will be made of reaction time, movement time, and force of movement, so a natural reaction charge or start is the desired movement.

SUBJECT INSTRUCTIONS: SET TIME TRIALS

1. On each trial you will take a preparatory set position with your feet resting on the starting block apparatus.

2. When you are ready, assume your set position by placing your right hand on the X mark on the tape switch signal pad. The hand support should always be on the knuckles, not the closed fist or fingers.

3. As you assume your set position there will be NO ready signal, however the equipment will be turned on at that time.

4. On each trial you will be given a pre-stimulus light signal which will act as the READY signal and which will indicate that a stimulus will occur in one second.

5. On each trial the warning light will precede the stimulus by exactly one second.

6. When the signal light comes on, you are to charge foreward in a running start and sprint to the tape line on the floor. Continue to accelerate until you have crossed the tape line.

7. You MUST perceive a stimulus before you react. You must make NO movement when the ready light is presented but you may prepare to react to the stimulus which will follow.

8. A maximum effort is mandatory on every trial.

9. Measurements will again be made of reaction time, movement time, and force of movement, so a natural reaction charge or start is the desired movement.

VITA

GEORGE WAYNE MARINO

BIOGRAPHICAL DATA

Date of birth:	April 14, 1948
Place of birth:	Niagara-on-the-Lake, Ontario, Canada
Married:	Shirley M. E. Jackson May 22, 1971
Permanent Home Address:	276 Davy St., Niagara-on-the-Lake, Ontario
Education:	B. A. McMaster University, 1971 B. P. E. McMaster University, 1971 M. P. E. University of Windsor, 1972

TEACHING AND RELATED EXPERIENCE

Summer 1972	Research Assistant, Faculty of Physical and Health Education, University of Windsor
1971-1972	Assistant Gymnastic Specialist, Dept. of Recreation, Windsor, Ontario

SCHOLARSHIPS AND AWARDS

1967	Niagara Lions Club University Entrance Scholarship

PROFESSIONAL ORGANIZATIONS

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